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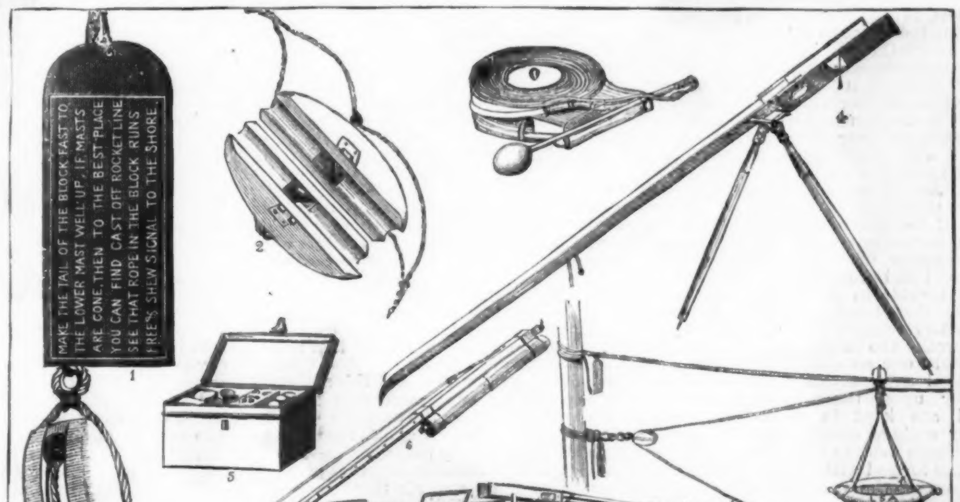
THE BRITISH LIFE SAVING ROCKET SERVICE.

THE Marine Department of the Board of Trade now maintains about three hundred stations furnished with complete life saving apparatus—195 on the coasts of England and Wales, 45 on those of Scotland, 51 on the Irish coasts, and others in the Isle of Man, the Channel Islands, and Heligoland, besides supplying many more with life belts and lines. The apparatus is under the charge of the coast guard, wherever there is a coast guard station; and in many cases there are companies of volunteers, not connected with the lifeboat service, who are enrolled up to a number sufficient, with the coast guard, or in the absence of coast guard, to provide twenty-five men for working the apparatus. They are to be under the orders of the local coast guard officer, the customs officer, the receiver of wreck, "or under the superintendence of some person of influence in the neighborhood."

The apparatus, and the method of working it, may be thus shortly described: A rocket is fired which carries a line over the ship, the crew haul on the rocket line, and this brings an endless rope (called a whip), rove through a block with a tail attached to it, which they make fast to a mast or some other portion of the wreck high above the water. Those on shore then haul off to the ship a hawser attached to the whip, which is made fast to the mast or other portion of the wreck about eighteen inches above the whip. Those on shore then set the hawser up, and send off to the ship the sling life buoy. When the buoy reaches the ship, one of the shipwrecked persons gets into it, and it is hauled back with its occupant. This process is repeated till all, or as many as possible, are saved. It is sometimes better to use the whip and sling life buoy alone. When the vessel is close in shore, the heaving cane is used instead of a rocket.

The rocket (No. 6 among the figures we have engraved) is that invented by Colonel Boxer, R.A., who devised a combination of two rockets in one case, one being a continuation of the other, so that the first compartment carried the projectile to its full elevation, and the second gave an additional impetus. The range thus obtained was found to much exceed that of two rockets attached side by side to one stick. This rocket was the same in principle as that now used, the "compound rocket," so arranged that when the first rocket has expended its force the second rocket is ignited, and carries the projectile further. The stick is 9 ft. 6 in. long, and is secured to the rocket by an iron pin. The line to be carried on board the ship is passed through a hole at the lower end of the stick, tied in a peculiar knot, and thence passed to a hole at the upper end of the stick, where it is secured by rings of India rubber and metal, and is tied again. The rocket is placed on the stand with a trough, called a rocket machine (Fig. 4), where the rocket fuse, at an opening in the side of the trough, is ignited by applying the portfire (Fig. 12). The handle of the portfire is a hollow case, which contains seven "primers" if required. It is lighted by a detonating primer, and so is the light (Fig. 10) used for signals or for illuminating the scene of a wreck. The portfire burns six or seven minutes; the fuse burns ten seconds. The line carried by the rocket is 250 fathoms or 1,500 feet in length, weighing 43 lb., and is barked or tanned to be more durable. When the end of the line is got on board the ship a "whip" is put upon it, by which those on land send out the block and tally board (Fig. 1). This is a black board, the size of a small school slate, with instructions painted on it, in white letters, in English and French, directing the crew what to do. They are bidden to make fast the tail of the block to the lower mast, or wherever they best can on board, and to see that the rope runs free in the block, and to signal this to the shore. The next business is to send out a hawser of three inch Manila rope, 120 fathoms long, with a second tally board, bearing further instructions to the crew, who are to make it fast and see all clear. The running rope in the block can then be used to bring men ashore on the hawser, as illustrated in Fig. 7, where the "breeches buoy" travels along by these means from the left hand, near the mast of the ship, toward the right hand of our engraving, in the direction of the shore. The lower part of the running rope is, of course, being hauled in by the volunteer life brigade and assistants. The breeches buoy is an ordinary cork life buoy, of circular open shape, with a bag of tarred canvas beneath, in which are two holes for a man sitting in the bag to put his legs through. It is attached to the "traveler block" on the hawser. The above described are the most essential working parts of the apparatus. Where the distance from the shore to the wreck is not above twenty yards or so, instead of firing a rocket, the men can throw a "heavy cane" by hand, with the line attached to it. This cane is twenty inches long, and is loaded at one end with nearly 2 lb. of lead. If ever it be necessary for those on shore to sever the hawser at the end near the wreck, to save it from being lost, or after all the people on board are rescued, this can be done by the "hawser cutter," which is armed with two knife blades (Fig. 2). The "whip" is an endless rope, 1½ in. thick, more than twice as long as the hawser, on which it works, being roved through a block, and moving freely when hauled from shore. If the shore is flat, the end of the hawser can be elevated upon the iron triangle (Fig. 14). The boxes for keeping the apparatus, and the wagon for its conveyance, are shown in other figures, as well as the mode of "faking" the rocket line, or arranging it for ready use, as laid in the box. The anchor for the hawser, the rope ladder for climbing the cliffs, and the helmet to protect the climber's head from loose falling stones, require no explanation.—*Illustrated London News.*



1. Whip Block and Tally Board. 2. Hawser Cutter. 3. Heaving Cane and Line. 4. Rocket Machine. 5. Fuse Box. 6. Rocket. 7. Whip, Hawser, and Breeches Buoy. 8. Cliff Ladder. 9. Wagon. 10. Light. 11. Rocket Line Box. 12. Portfire. 13. Showing Rocket Line "faked" in box. 14. Triangle. 15. Anchor. 16. Cliff Helmet.

ROCKET APPARATUS OF THE BOARD OF TRADE FOR SAVING LIFE FROM SHIPWRECK.

THE MEIGS ELEVATED RAILWAY.

THE roadbed and rolling stock of the railroad of to-day have reached their high standard through the labors of countless ingenious and persevering inventors, each of whom has added his link to make the chain more perfect; even the smallest detail shows the combined talent of many industrious workers, one taking it up, advancing it a step, and then giving place to another. It therefore seems peculiar to be called upon to describe a new method of railroading designed as a whole by one man—a new railroad from the ballast to the top of the smokestack, from the pilot to the coupler on the last car.

The system herewith illustrated is the invention of Mr. Joe V. Meigs, of Lowell, Mass., and has been tested under conditions far more exacting than would be found in actual practice. The road is not a model, but a full sized elevated railroad in every respect. This was made necessary by a section in the act of the Massachusetts Legislature authorizing the incorporation of the Meigs Elevated Railway Company, which states that "no location for tracks shall be petitioned for in the city of Boston until at least one mile of the road has been built and operated, nor until the safety and strength of the structure and the rolling stock and motive power shall have been examined and approved by the board of railroad commissioners or by a competent engineer to be appointed by them." To fully demonstrate the possibilities of the road under widely varying circumstances, the company has built tracks of several kinds—wooden way of the cheapest possible kind; wooden way following the contour of the earth; wooden way with level grade secured by varying the heights of the posts; wooden way with very short curves and steep grades; and iron way upon high grades, increasing in height until a level of 14 feet in the clear above the earth was secured. The trial road beginning at the shops of the company on Bridge St., East Cambridge, has one curve of 50 feet radius, 165 feet long, on a grade of 120 feet, and on level and curves has grades of 240 feet, 300 feet, and 345 feet. So far everything has worked in the most satisfactory manner, the train rounding the exceedingly sharp curves easily, and mounting the steep grades without trouble.

The peculiar features of this road, wherein it differs

most essentially from the ordinary railroad, are the way, switch, trucks, passenger cars, engine, drawbar, and brakes.

The posts for an iron way are made up of two channel bars united by two plates, thereby forming a box-like structure whose cross section may be varied as demanded by location. The posts are to be placed upon foundations, the plans of which vary to suit the character of the material that may be encountered.

The way upon which the train runs consists of a single iron girder 4 feet in depth for each span, placed over the center line of the posts. The girder carries an upper track beam and a lower track beam, upon the sides of each of which the rails, four in number, are placed. The two bearing rails, which carry the load of the train, consist of angle irons placed upon the outer upper edge of wooden stringers upon the lower track beam. These stringers are placed in the exterior recesses formed by two channel bars properly secured to the sides of the posts. These rails are fastened to each other, to the stringers, and to the track beam by bolts passing clear through. Two vertically placed rails for the balancing or friction wheels are carried by the upper track beam. The distance from out to out between the lower rails is 22½ inches, this being sufficient to insure the necessary transverse stiffness. This is the gauge of the road. The distance between the upper rails is 17⅛ inches. It is expected to adopt the common form of rail, beveling the edges of the lower stringers and placing the rail at an angle of about 45 degrees. In our engraving, the rails are in the form of a right angle, and the treads of the wheels are made with a corresponding right angle groove. The usual length of post, 24 feet, would give a clear headway of 14 feet, 4 feet being taken up by the truss and 6 feet forming the foundation.

The switch is formed of a single swinging section turning upon a hinge of great strength attached to one of the posts. A movement of four or five feet by the free end of the switch is enough to permit the cars and trucks on one track to clear the end of the other track. The free end travels upon a carriage provided with rollers moving upon a supporting rail. Suitable mechanism is provided for operating the switch and locking it in place.

The truck is a development of the conditions controlling the adoption of the permanent way. It consists of a horizontal rectangular wrought iron frame, stiffened by cast iron pieces and provided with stiff pedestals bolted to its under side, in which is a fixed short axle for the wheels. Each truck has four wheels set at an angle of about 45 degrees, the axles being properly inclined. Between the supporting wheels are two horizontal wheels, one on each side of the upper girder, upon vertical axles attached to the frame; these wheels bear upon the rails of the upper truck beam, and are kept in yielding contact with the rails by springs outside the boxes, and serve as balancing wheels to take the side oscillations of the cars. They are formed with flanges that pass under the lower edges of the rails, thus tying the truck to the rails, so that no lifting or jumping can take place, and there is no possibility of the trucks running off the track. The wheels are 42 inches in diameter, have a tread of 3⅛ inches, and rotate independently of each other. In case any or all of the wheels should break, provision is made to prevent the cars from overturning or leaving the track, by means of a strong shoe, which would slide upon but could not leave the way. On top of the truck frame is a movable iron frame carrying four posts containing heavy spiral springs. These posts interlock with similar spring sockets bolted to the framing of the floor of the car, which is directly above the truck and within 18 inches of the top of the girder. The truck is guided in turning by a center pin, and is securely tied to the car body, as the horizontal flanges of its frame castings overlap the rim of the upper turntable. In passing curves and switches, the trucks turn upon the balancing wheels placed centrally between the supporting wheels, which are 4 feet apart.

It has been found that, by reason of the independent motion of all the truck wheels, curves are followed so closely that practically the increase of friction of the cars upon curves even as small as 50 feet radius is too slight to be noticed or measured by weighing in a model one-eighth full size. This construction of the trucks also admits of a car 50 feet long turning from a street only 28 feet wide into another of the same width.

The cars possess many novel features, both outside and inside. The circular section and rounded ends admit of the strongest possible construction without an overweight of material. The floor consists of a platform made of 5 inch channel beams, and is 7½ feet wide by 51 feet 2 inches long. The framing of the body is of light T iron ribs, bent in a circle, filled in by panels covered with rich upholstering, which covers all the interior; the exterior is sheathed with paper and copper. The cylindrical portion is 10 feet 8½ inches in diameter. While adding to the strength, this form is expected to diminish the wind resistance fully one-third. The interior of the car, as shown in Fig. 1, is light, roomy, and pleasing to the eye. The seats are upholstered like the rest of the car, and comfort and luxury have been carefully studied in every detail. At each window is a specially designed device for securing ventilation without the annoyance caused by dust. There is an entire absence of sharp corners, so that, in case of a serious accident, the liability of the passenger being greatly injured is largely avoided.

The locomotive consists of a platform car supported upon a truck at either end and housed like the passenger car. The floor is 7⅛ ft. wide by 29⅛ ft. in extreme length; the tender is 25⅝ ft. long, has a tank and bin for the water and coal, besides additional room which may be used for other purposes. Upon the floor of the engine are, in effect, two complete stationary engines, each connected with a single driving wheel. The boiler is of the locomotive type, is 60 in. in diameter, 15 ft. in length, and is placed over the engines, its center line being 61 inches above the floor. There are 200 tubes, 2 in. in diameter and 7 ft. long; the grate is 4½ ft. square. The crown sheet is arched in shape, and is inclined downward at the back end to allow of climbing and descending grades equal to 800 feet to the mile without exposing any uncovered part to the fire. The cylinders are 12 by 22 in., and their center lines are placed 18 in. above the floor and 61 in. apart. The piston rods connect with independent crossheads sliding upon steel girders supported at their ends by standards bolted to the floor beams.

The driving wheels are 44·6 in. in diameter, flanged upon their lower edge like the balance wheels of the trucks, and are mounted upon steel axles 6 in. in diameter, which extend through a sliding box containing the journals. The boxes slide in cast iron ways placed at right angle to the line of the engine, and each axle has a crank keyed upon its upper end. The well known slotted yoke connection is used. The slide valves are of the usual locomotive form. The links are placed in a horizontal instead of a vertical position, and are operated by two bell cranks. The throttle valve, link rod, brake, and coupling rods, and the connection between the driving boxes for producing pressure against the rails, are operated by hydraulic power, although hand levers are also provided.

Adhesion of the driving wheels to the rails is obtained by means of a cylinder and piston secured to the sliding boxes. The engineer is on an elevated platform in the front part of the engine, the fireman being at the rear end. The former has an unobstructed view through the windows of the monitor roof, and before him are five hydraulic cocks, which control the throttle, links, sliding boxes of the driving wheels, the brake, and the coupling rods of the entire train, while just above are steam and hydraulic pressure gauges and indicators, whistle and bell ropes, etc. With an engine thus furnished with provisions for griping the rails, steep grades become of minor importance, as the steepest possible can be ascended if the requisite power is provided.

One turn of the cock controlling the couplings divides the train into segments of separate cars, each of which has a brake which acts automatically upon detachment from the train. This partially destroys the momentum of the whole, and a collision could only take place by a succession of comparatively light blows from the engine and slowing sections of the train, instead of by a single blow with the momentum of the whole train.

The brakes are operated upon the balancing wheels of the trucks, but they may also be fitted upon the supporting wheels. The action of the brakes is well illustrated by rails between the rolls of a rolling mill, except that the action is reversed. It is apparent that no slipping of the wheels can take place, no matter what pressure may be brought to bear upon them.

In the illustration, Fig. 2 is a plan view of a train on a sharp curve, Fig. 3 is an end view of the track and engine, Fig. 4 is a section through tender and track, and Fig. 5 is a section through the car.

From the foregoing it will be seen that this system is as applicable for surface as for elevated railroads. It may be more cheaply built than the ordinery road, as the construction of the rolling stock allows the contour of the ground to be more closely followed. As an elevated road in cities, the permanent structure presents far less obstruction to light and air than the usual form. The center of gravity of the cars and engine is brought as low as possible, thereby lessening the effect of leverage caused by wind pressure. The smooth, even surface of the exterior of the entire train serves to decrease the resistance to the wind, and permits a high rate of speed.

REPORT OF ENGINEER STARK.

The following is an abstract of the report made to the Board of Railroad Commissioners of the State of Massachusetts, "on the safety and strength of the structure of the Meigs elevated railway, so called, in Cambridge, and the rolling stock and motive power used thereon," by Gen. Geo. Stark, an engineer connected with the Northern Pacific Railroad.

The structure has been erected wholly on made land, upon what was once the bed of Miller's River, and the mud underneath this made land is soft and deep. In addition to this natural difficulty, Capt. Meigs has purposely introduced artificial obstacles in his track, for the purpose of showing that he can run his trains around curves of less radius and on grades of greater elevation than are now practicable on ordinary steam motor railways, and can safely pass horizontal or vertical angles in the track, of very considerable deflection. One of his curves makes an entire semicircle, with a 50-foot radius, on a grade of 120 feet to the mile, and another turns nearly a quarter circle, with a radius of 50 feet, on a grade of 345 feet to the mile.

The construction of the track is simple, and the question of its strength and safety is easily determined. The entire structure consists of a single line of girders supported on a single line of posts. The two rails on which the bearing wheels supporting the load run being placed on the upper outside corners of the lower boom of the girder, and the two rails that resist the pressure of the horizontal driving and guiding wheels being placed on the outer sides of the upper boom of the girder. The problems to be solved are, first, as to the strength of girder for sustaining a vertical load represented by the fixed weight of the girder and the moving weight of the train passing over it, and for resisting the horizontal strains and twists that may come either from the grip of the driving wheels or the momentum of the train or the action of wind; and, second, as to the strength of the posts for sustaining the weight of girders and trains and their stability and power of resistance against side pressure, caused by momentum or wind blowing upon the side of the train.

The railway company has submitted to my examination extensive and thorough computations, made by engineers in their employ, to show the force of these various strains and the amount and form and quality of material required in the girders and posts to safely resist and bear the loads and strains to which they are, or may be, subjected. These computations show that the structure as built, is, theoretically, of ample strength and stiffness, under all circumstances, to safely carry the train; and the numerous trips that I have myself made over it with the locomotive and cars practically verify these theoretical calculations.

But for the purpose of more tangible verification, I caused one of the longer girders to be loaded, in my presence, with a known weight of nearly double the amount that could be brought upon it by the train, and noted myself the results by gauges arranged to show the deflection. The girder experimented upon is about 46 feet long, and its lower boom is about 18 feet above the surface of the ground. Two large iron cylinders (rendering tanks) laid on cross timbers were suspended under the exact middle of the girder by means of a heavy chain passing over the upper boom. The tanks were then filled with water, making an aggregate weight of water, tanks, chain, and timber of 60,187 pounds, or about 30 net tons, equal to a distributed weight of 60 tons upon the girder—a load greatly in excess of any that could ever be put upon it by the train. The depression of the girder at its center under this load was seven-sixteenths of an inch. And, on removing the load, the girder sprang back to its original position.

To test practically the power of the girder to resist lateral strains arising from pressure of wind and unbalanced loads, computations have been made, based upon the force of a hurricane blowing 110 miles an hour squarely against the side of the train, when the load is out of balance by passengers being at the same time all on the leeward side of the car. And the side pressure on a girder arising from these extreme conditions is computed to be equal to about 4 42-100 tons. By means of a cable attached to the center of a girder, and passing horizontally over a loose pulley in the top of a shear, and suspending vertically a platform loaded with pig iron, I applied a force of 5 29-100 tons, to pull the girder sidewise, being an excess of 20 per cent. over the computed extreme force of combined hurricane and unbalanced load. The side deflection of the girder at its middle caused by this pressure of 5 29-100 tons was three-eighths of an inch. This pressure caused the posts supporting the girder under test to bend at their tops one-half of an inch. On removing the weight, the girder and posts sprang back to their original positions.

As the iron posts are of good design and well built, and securely fixed in place by foundations of timber and concrete, and have stood the pressure and strain of the train passing over them at frequent intervals for some months, I consider them satisfactory, and that no further test of their strength is necessary. The method of filling them with concrete, so arranged as to mainly take the weight, instead of leaving it to be supported by the iron shell, is especially commendable.

The wooden posts now in use on the low part of the structure answer very well for experimental purposes, but in a line intended for city traffic I should advise that iron posts, filled with concrete, be adopted in all cases.

The structure of this experimental piece of railway, as now submitted to my examination, is, in my opinion, safe, and sufficiently strong, except in the plate angle iron rails on the lower boom of the girder, which have proved too light, and are about to be replaced with heavier ones. It contains, however, objectionable curves and grades and angles, purposely placed there for extreme tests, to show what obstacles may be overcome if necessity compels them to be encountered, and to find out what changes may be desirable in the proportions of the machinery. In my opinion these extreme features should be eliminated, and, wherever possible, kept out from any line intended for business purposes.

The motive power and rolling stock submitted to my examination consist of a locomotive weighing about 30 tons, a tender weighing about 14 tons, and a passenger car weighing about 17 tons, making up a train of about 61 tons, aggregate weight, when empty.

Excepting the distinctive running gear, or trucks, of this railway system, the general features of the motive power and rolling stock correspond to, or are supposed improvements upon, the locomotives and cars of ordinary steam railways.

A cylindrical shape has been adopted for all the equipment; for which shape peculiar advantages are claimed as to safety, convenience, and economy, and particularly as to offering less resistant surface to the wind.

The car is more elegant and commodious internally than ordinary cars, and, being largely built of metal instead of wood, is safer as regards fire, or as regards splinters, in case of accident. The turntable arrangement of the trucks also seems stronger and safer than the trucks now in common use.

The leading features of the system center in the trucks. They are constructed to straddle the girder, so that, if all the bearing wheels were knocked off, the fall of the truck would not be over two or three inches, on to the top boom of the girder, on which it would slide or rest.

The wheels that bear the weight, instead of being placed in the ordinary upright position, are fixed at an angle of about 45 degrees from the vertical plane. The bearing face of the wheels being grooved to fit down upon the angle iron supporting rail, on the upper corners of the lower boom of the track girder, so as to bear both downward and inward on the rail. Each wheel has its own independent axle, securely fixed in the iron jaw of the truck, at right angles to the plane of the wheel. By this arrangement, the axle strains and the slipping of wheels on curves, so troublesome in wheels and axles of the ordinary construction, is wholly avoided; and it becomes possible to use sharper curves in the track than have ever before been practicable. Each truck has also two horizontal guide wheels, bearing against the rails on the sides of the upper boom of the track girder, to pervent the truck from swaying.

As the sustaining rails of the track on the lower boom of the girder are but 22½ in. gauge, and the wheels stand sloping outward from these rails, on an angle of about 45 degrees, the first appearance of the rolling stock, to a casual observer, is one of extreme instability. But upon investigation and practical test, this appearance is found to be deceptive. Careful mathematical and mechanical analysis of the arrangement of the wheels and axles shows the plan to be theoretically correct; and that, as a matter of fact, this arrangement of trucks, upon properly constructed girders, is more stable and more safe than the trucks of ordinary rolling stock upon the ordinary railroad tracks.

For the purpose of testing the safety of these trucks in the event of accident, I caused one wheel to be removed from a truck under the car, so that the car would be in the condition of losing a wheel by breakage while in motion. The train was then run over the track with one wheel gone. There was no perceptible tipping of the truck on account of the absence of this wheel, and no apparent tendency to derailment. The absence of the wheel would not be noticeable to passengers in the car.

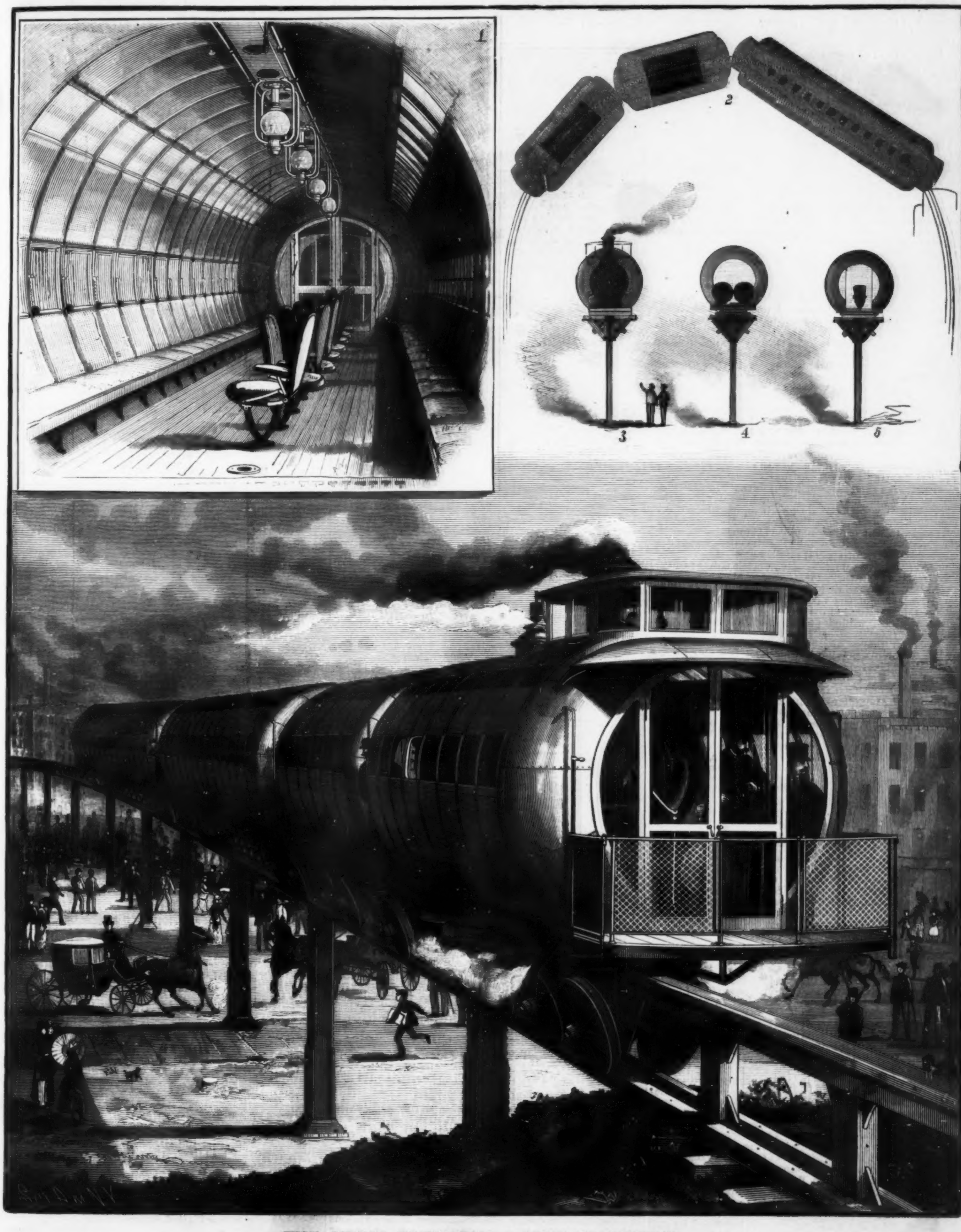
I also caused a section of the supporting rail and

timber of one side of a lower boom to be cut away and removed, leaving an open gap of about six feet in the track. The car was then pushed over this gap, and, of course, became derailed; but it only dropped about two inches, and slid along on the upper boom as securely as if on its wheels. The center of gravity being but little above the boom on which the car rested, the side wheels and truck jaws held the car effectually in horizontal position, with very little strain. Apparently, a derailed car, on this system, could not tip over, which cannot be said of ordinary railroad cars on the ordinary railroad tracks.

The locomotive has some minor novelties of construction besides the truck arrangement above alluded to, not necessary here to describe; but its main features are the horizontal driving wheels, which pull the train by side pressure on the rails of the upper boom of the girder, and the hydraulic attachment by which the pressure or adhesion of these driving wheels upon the rails is created, maintained, and regulated, at will, by the engine driver.

This motor has accomplished some remarkable feats. It draws itself and the attached train, with apparent ease and at great speed, around sharper curves and up heavier grades than the ordinary locomotive can pass. But being the first of the kind ever built, of full size, and having been from the outset put at work on a track purposely planned to bring out in this experimental stage any existing weakness of design (through trial on unusual grades and curves and angles, requiring machinery of great perfection and power to overcome these extraordinary obstacles), it has, as might be expected, proved weak in some of its minor proportions, and there has been more or less breakage in the strained parts. All the defects thus far developed seem, however, to be susceptible of easy remedy, and no doubt, in future construction, the proportions of the parts will be greatly improved.

With so radical a departure from the ordinary mode of applying locomotive power, it is only to be expected that perfect proportions will develop slowly, and out of the results of extended use or practical experiments. This is but the usual rule, applying to all inventions. The result of my investigations may be summed up as follows:



THE MEIGS ELEVATED RAILWAY SYSTEM.

The experimental section of the Meigs elevated railway now in use at East Cambridge is, in my opinion, abundantly strong for its intended use as an elevated railway track, and is safe for the passage of its equipment.

The rolling stock and motive power used thereon is also strong and safe for its intended use, no breakage having occurred, or being likely to occur, that could imperil personal safety, either in or out of the cars.

A line of railway, properly constructed on this principle, for passenger or freight traffic, and equipped with such rolling stock and motive power, on this principle, as the Meigs company is now prepared to perfect and build, would, in my opinion, be at least as strong and safe for any kind of traffic as the ordinary surface or elevated steam railways now in common use.

In view, however, of the imperative necessity for the best class of design and construction in everything appertaining to an elevated railway, I think it would be wise for the State of Massachusetts, through its board of railroad commissioners, or otherwise, to regulate the strength and design of all material used in construction, and the weight and design of equipment to be run, etc., as is done by New York through its "rapid transit commission" for elevated railroads in that State.

IMPROVED GAS FIRE.

MR. WILLIAM FOULIS, General Manager of the Glasgow Corporation Gas Commissioners, has devised a gas fire in which is embodied a new departure in domestic firing by the use of gaseous fuel.

It may be premised that the essential point in the construction of this new form of gas fire is that the combustion of the gaseous fuel shall, as nearly as possible, be completed in a separate combustion chamber, without the flame coming into direct contact with the material that is to be rendered incandescent. This principle has guided the inventor in his labors, because of the now well-known fact that the contact of flame with even red-hot surfaces exerts an injurious effect on the process of combustion. It is the same principle that Mr. F. Siemens has so forcibly dwelt upon during the past two or three years. In order that he might attain the object aimed at—viz., the most perfect combustion of the gas that is practically possible—Mr. Foulis has adopted in his gas fire a special combustion chamber, lined with fire-bricks, and situated underneath the material in which the heat is to be rendered visible. It is in this chamber that the combustion takes place. The chamber has a lining of four special fire-bricks—one on the top, one at the bottom, and one on either side; and consequently the flame never comes in contact with the cast iron forming the outer shell of the fire. As this lining consists of highly refractory material, it very soon attains a high temperature; the chamber becoming, in reality, a sort of furnace on a small scale, in which the flame heat is most intense.

The material used for simulating the coal or coke fire is a fire-clay brick of special quality and peculiar construction; the front portion of the brick being formed of an irregular fretwork, so as to resemble as closely as possible a mass of brightly glowing coal or coke. For the largest size of the new gas fire the burner brick measures some 9 or 10 inches across, and it is about 7 inches in height, while its thickness is 3½ inches. Its posterior surface, where it lies in contact with one of the cast-iron plates of the stove, is quite flat and unbroken. This portion of the brick is about 1 inch thick; and on its front surface are formed a series of ½ inch ribs or "gills," with intervening flutings. Then the front portion of the brick is moulded upon this in a very irregular manner by hand, and there is left a flame space in which a complete system of "baffling" is effected. On the lower edge of the burner brick there are left a series of openings corresponding to the number of Bunsen burner tubes used in each gas fire. At present two sizes of fires are being made, one having six burners and the other four. The larger of the two fires is designed to consume 36 cubic feet of gas per hour. Each burner has a stopcock, so that the intensity of the fire may be modified at pleasure.

In finding their way through the baffled passages of the burner brick, the highly heated products of combustion raise it to nearly a white heat in its lower half; the heat gradually diminishing to a bright red in the upper portion, so that the appearance which a "good-going" fire presents to view is one of the very best "make-believes" yet brought under public notice. The hot products of combustion pass upward to a certain level, and then their course is directed downward and outward by a flue at a low level to the chimney. Immediately at the back of the descending flue just referred to there is another, by means of which fresh air is admitted. This finds entrance at the bottom portion of the fire. The plate forming the back of the descending flue has cast on it a series of "gills," each about ¾ inch in breadth; and in this way there is provided a large amount of surface for the fresh air to come into contact with, and absorb its heat. The air so heated finds its way into the atmosphere of the apartment without being, even in the slightest degree, contaminated with the products of combustion or with unconsumed gas. There is also a hot-air space or chamber, having a width of about ½ inch, at each side of the stove. The air heated in the manner explained escapes into the atmosphere of the room by a series of fretwork apertures placed immediately under the top of the fire and in front.

Referring now briefly to the accompanying illustrations, we may state that Fig. 1 shows the general appearance of the new gas fire. The fire is represented as being set out some distance into the room on a flooring of encaustic tiles, which also form the "backing" of the fire. A certain amount of ornamentation is likewise imparted to the fire by inserting a couple of tiles in front of the combustion chamber, and a like number in the top of the fire. By means of horizontal bars connected by two upright pieces, another touch of resemblance to the coal-fired grate is imparted to this open gas fire or stove. To some extent this arrangement of front bars also forms a sort of protection to the burner bricks. In some cases the fire is made with a trivet fitting placed beneath the front bars. The lighting of the fire is done through a small peephole on either side. Fig. 2 is a sectional view of the fire. At A is the burner brick, with its front of irregular fretwork. It is this that becomes incandescent by the hot products of combustion passing upward from the combustion chamber, B. The principal air supply to the burners is drawn through the passage, C, in which it becomes heated before entering the combustion chamber; so that this part of the fire acts as a regenerator. So far as we are aware, this is the only gas fire in which the regenerative principle has been effectively carried into practice. In saying this we are not unmindful of the fact that the late Sir W. Siemens made an attempt in the same direction in his gas and coke fire, which excited some attention at South Kensington a few years since. The hot gaseous products of combustion, after passing through the interstices within the burner brick, find their way (as indicated by the

FIG. 1.—FOULIS' GAS FIRE.

arrows turned downward) through the flue to the outlet into the chimney, E. The cold fresh air is admitted at the openings at D, and it passes up through the chamber, F, where it becomes heated, and eventually finds its way into the atmosphere of the room, to be heated through the apertures shown at G.

It should here be mentioned that both sizes of the gas fire now being made may also be had without the arrangement just referred to for supplying a current of warm fresh air to the apartment. In its complete form, however, the fire is certainly one of the most efficient appliances of the kind yet devised for heating by gas. At the same time it possesses some artistic beauty, which makes it pleasing to look upon; while

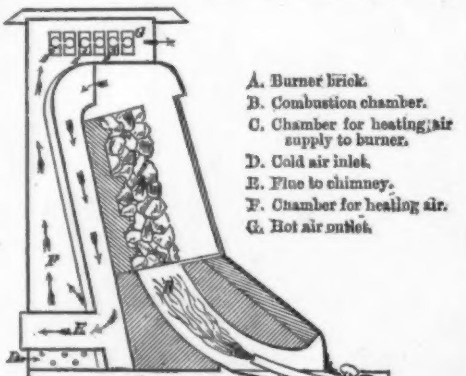


FIG. 2.—SIDE SECTION OF FOULIS' GAS FIRE.

the glowing heat which it disseminates engenders a physical pleasure that has only been enjoyed hitherto from an open coal fire. Made by R. & A. Main, of Glasgow.—*Journal of Gas Lighting.*

THE GAS COMPANIES OF AMERICA.*

By WM. W. GOODWIN.

THE number of gas companies in the United States, as near as can be determined, is 971; in the Dominion of Canada, 47; or a total for both of 1,018.

Of these companies, 888 in the United States responded, in a greater or less degree, to our request for information, and 83 failed to reply. Of the companies in the Dominion of Canada, 40 replied, 7 failing to respond.

Of the 888 companies in the United States that replied to our inquiries, 592 manufacture gas from coal, and 296 manufacture under one or another of the various patents and processes known as simple water gas, or water and oil, water, coal, and wood, etc., systems.

In the Dominion of Canada, out of the 40 replying, 24 companies make gas from coal, and 16 from all other processes.

The 971 companies in the United States employ 2,801 persons, who fill the respective offices of president, secretary, treasurer, superintendent, and engineer. In some of the companies several of these positions are filled by one person.

Of the companies in the United States that replied, 140 gave process and price, but nothing in regard to output; 38 gave process, but nothing as to prices and output; 7 mentioned output and process, but no prices; 5 gave prices, but neither output nor process; 1 gave output, but no price or process; and 72 were silent on all the foregoing particulars. In Canada, of those that replied, 2 gave price and output, but nothing as to process; 1 mentioned price and process, and was silent as to output; 1 returned process, and said nothing about price or output; while 4 were silent on these items.

PRICE CHARGED PER THOUSAND CUBIC FEET.

United States.

No. Cos.	Rate.	No. Cos.	Rate.	No Cos.	Rate.
1	$0 75	1	$1 93	100	$3 00
1	90	190	2 00	1	3 15
10	1 00	4	2 10	2	3 20
1	1 10	1	2 12	2	3 25
5	1 25	1	2 15	33	3 50
7	1 40	4	2 20	3	3 60
1	1 43	63	2 25	1	3 75
38	1 50	2	2 30	22	4 00
1	1 52	2	2 35	1	4 25
10	1 60	3	2 40	7	4 50
1	1 62	1	2 43	15	5 00
2	1 65	1	2 44	9	6 00
1	1 66	173	2 50	1	6 50
4	1 70	2	2 60	3	7 00
25	1 75	6	2 70	3	8 00
1	1 77	21	2 75	5	10 00
23	1 80	4	2 80	1	20 00
3	1 90	3	2 85		

PRICE CHARGED PER THOUSAND CUBIC FEET.

Canada.

No. Cos.	Rate.	No. Cos.	Rate.	No. Cos.	Rate.
1	$1 25	10	$2 50	8	$3 00
5	1 50	1	2 63	1	3 20
5	2 00	1	2 70	2	3 25
5	2 25	1	2 80	1	4 00

PRICE RECEIVED PER YEAR FOR PUBLIC LAMPS.

Canada.

Rate.	No. Lamps.	Rate.	No. Lamps.	Rate.	No. Lamps.
$13 80	160	$20 00	3,932	$25 00	44
14 00	18	20 50	2,417	27 00	55
15 00	902	22 00	244	28 00	126
15 50	126	22 50	47	30 00	92
16 50	29	22 75	173	40 00	67
18 00	20	23 00	142	2 50 per M	60
19 40	275	24 00	184		

Total number public lamps 9,113

PUBLIC LAMPS IN UNITED STATES, MAINTAINED AND PAID FOR IN VARYING MANNER, AS STATED IN HEADINGS.

No. Lamps.	Per Hour.
356	$0 01
100	1⅕
142	14/15
100	1¼

No. Lamps.	Per Night.
315	$0 05½
150	6
50	6½
215	9
5,100	13
25	4⅔
70	7¾

No. Lamps.	Per Month.
55	$1 00
416	1 75

No. Lamps.	Per 100 Cu. Ft.
55	$1 00

No. Lamps.	Per 1,000 Cu. Ft.
1,500	$0 55
2,800	71
1,407	75
7,476	1 00
5,161	1 05
671	1 20
7,000	1 23
40	1 25
5,769	1 30
1,856	1 40
24,844	1 50
841	1 60
1,833	1 65
99	1 70
4,311	1 75
1,693	1 80
1,752	1 85
545	1 90
500	1 95
5,688	2 00
900	2 25
44	2 35
1,428	2 50
104	2 65
35	2 70
390	2 75
89	2 80
564	3 00
41	3 10
171	3 50

No. Lamps.	Per 1,000 Cu. Ft.
21	$3 60
42	3 80
212	4 00
11	5 00

No. Lamps.	Each Per Year.
218	$6 00
25	8 00
85	9 60
186	9 78
176	10 00
129	10 50
70	10 71
2,802	12 00
528	12 28
726	12 50
405	13 00
43	13 40
178	13 50
251	14 00
180	14 25
72	14 40
500	14 50
107	14 72
269	14 75
3,058	15 00
50	15 36
112	15 50
131	15 60
2,000	15 63
485	16 00
162	16 25
545	16 50
1,222	16 66
46	16 75
94	16 80
763	17 00
70	17 15
60	17 40
116	17 41
19,035	17 50
959	17 75
58	17 76
400	17 80
7,478	18 00
1,703	18 12
68	18 50
103	18 72
431	18 74
1,686	19 00
301	19 20
76	19 25

No. Lamps.	Each Per Year.
31	$19 35
1,306	19 50
2,495	19 80
4,899	20 00
132	20 52
700	20 95
1,523	21 00
299	21 50
2,700	21 75
7,531	22 00
1,638	22 50
3,042	23 00
100	23 25
235	23 32
87	23 40
51	23 50
61	23 72
4,756	24 00
6,563	25 00
233	25 15
127	25 50
279	26 00
48	26 50
1,199	27 00
262	27 50
3,996	28 00
707	29 00
6,919	30 00
232	31 20
518	32 00
1,779	33 00
386	35 00
604	36 00
3,340	37 00
121	37 20
1,033	37 50
340	38 00
38	38 50
110	39 00
156	40 00
35	40 30
3	42 00
46	43 20
27	43 25
225	44 76
95	45 00
384	48 00
267	49 20
39	50 00
110	52 20
55	60 00
14	66 00
21	69 00

RECAPITULATION OF ANNUAL OUTPUT, SELLING PRICE, ETC.

United States.

	Annual Output. Cubic Feet.	Amount Received.	Av. Price per M.
Coal process	17,502,305,000	$30,452,710	= $1.73 $\frac{22}{100}$
Other processes	5,554,401,800	10,291,963	= 1.85 $\frac{29}{100}$
All processes combined	23,056,706,800	$40,744,073	= $1.76 $\frac{71}{100}$
Processes other than coal at $6 or less per M.	5,526,301,800	$10,014,263	= $1.81 $\frac{3}{10}$

* A paper read at the fourteenth annual meeting of the American Gas Light Association, Philadelphia, Pa., October, 1886.

If "other processes" in excess of \$6 per M be deducted, the grand average price will be \$1.75$\frac{78}{100}$ per M.

RECAPITULATION OF ANNUAL OUTPUT, SELLING PRICE, ETC.

Canada.

	Annual Output. Cubic Feet.	Amount Received	Av. Price per M.
Coal process........	629,500,000	\$1,102,665 =	\$1.75
Other processes....	396,950,000	600,475 =	1.51
All processes combined...........	1,026,450,000	\$1,703,140 =	\$1.65$\frac{93}{100}$

Total number of public lamps maintained in consideration of a fixed sum per lamp per annum equals 100,004, and the gross annual amount received for same equals \$3,319,287.85, or an average price of \$30.17 per lamp per annum. The total lumber of lamps annually maintained in consideration of rates of payment other than a fixed sum per lamp per annum equals 86,897. Adding the two, we have a grand enumerated total of public lamps in the United States equal to 186,901.

In order to more vividly appreciate the vast magnitude of the business of the gas manufacturers of our country, the quantities of material used in that manufacture, and the vastness of the product, I have made various forms of calculation which will present the subject in such shape as to be readily realized and understood. Few persons comprehend the magnitude of anything whose aggregate is presented to them in figures requiring the term billions, further than to understand that something very great or immense is meant; but when presented in a representative form or comparison, these magnitudes are better comprehended.

The annual output of the 495 coal gas companies of the United States amounts to 17,502,305,000 cubic feet, and that of those in Canada to 629,500,000, or a total of 18,131,805,000 cubic feet, which required for its production about 3.817,222,105 pounds, or 1,908,611 tons, of coal, and would require 159,050 cars (each car having a carrying capacity of 12 tons) for its transportation. These, if divided into trains of 40 cars each, would equal 3,976 trains; and if the locomotive of each train touched the rear car of the preceding train, they would cover a track 903 miles long—allowing 4·4 trains to each mile. If the coal were placed on the ground, it would form a road 6 feet wide, 1 foot deep, and 2,549 miles long; or would make a belt around the world about 8 inches deep and 12 inches wide.

In the matter of the residual products obtained from the distillation of the total quantity (1,908,611 tons) of coal annually carbonized, we have the following results:

Ammoniacal liquor, at 23 gallons per ton, equals 43,898,053 gallons, which, if turned into sulphate of ammonia, would produce 30,000,000 pounds.

Tar, at 12 gallons per ton, equals 22,903,332 gallons.

Coke, at 0·75 ton per ton of coal, equals 1,431,459 tons =43,943,770 bushels.

Benzine, at 1·1 pounds per ton, equals 2,099,472 pounds.

Aniline, at 1·1 pounds per ton, equals 2,099,472 pounds.

Solvent naphtha, at 2·4 pounds per ton, equals 4,580,666 pounds.

Naphthaline, at 6·3 pounds per ton, equals 12,024,249 pounds.

Naphthol, at 4·75 pounds per ton, equals 9,065,903 pounds.

Yellow naphtha, at 9·5 pounds per ton, equals 18,131,804 pounds.

Creosote, at 17 pounds per ton, equals 32,446,387 pounds.

Heavy oils, at 14 pounds per ton, equals 26,720,554 pounds.

Anthracine, at 0·46 pound per ton, equals 877,961 pounds.

Alizarine, at 4·25 pounds per ton, equals 4,294,374 pounds.

Pitch, at 69·6 pounds per ton, equals 132,839,325 pounds.

Phenol, at 1·5 pounds per ton, equals 2,862,916 pounds.

The colors derived from the coal would dye to a full shade of magenta (at 500 yards per ton) 954,305,500 yards of flannel 27 inches wide. Naphthol (yellow, at 3,800 yards per ton), 7,252,721,800 yards flannel 27 inches wide. Aurine (orange, at 120 yards per ton), 229,033,320 yards flannel 27 inches wide. Alizarine (Turkey red, at 225 yards per ton) would dye 429,437,475 yards of calico.

The annual output of the 206 companies employing water or other processes equals 5,952,101,800 cubic feet, which would require for its production about 357,126,060 pounds (or 178,563 tons) of coal. That weight of coal would require 14,880 cars—capacity of each as before—for transportation. The trains, if allowed 40 cars to each, would number 372; and if the locomotive of each train touched the rear car of the preceding one, a track 84½ miles long would be occupied.

The quantity of oil used would equal about 29,760,505 gallons, requiring to move it 240 trains of 40 cars each, arranged as the coal trains were, and covering a track 56¼ miles in length. The oil used would fill a main 751 miles long and 13·56 inches diameter. The total quantity of gas manufactured would fill a main 13·56 inches diameter (equal to 1 square foot) and 4,651,346 miles long. That is equal to 19 times the distance of the moon from the earth; or it would fill a pipe of same diameter that would encircle the earth 190 times, or would fill a single pipe leading from the earth to the moon having a diameter of about 59 inches. The total annual output of the 723 companies mentioned in this calculation in the United States and Canada—*i. e.*, using coal and other processes—equals 24,083,906,800 cubic feet, and would supply 4,816,781,360 five-foot burners for 1 hour. If each flame had a superficial area of 6 square inches, it would support for one hour a flame having a total area of 200,698,456 square feet; or a band of flame one foot wide and 30,011 miles long, burning one hour; or a flash of flame, one second in duration, 1 foot wide, and 136,839,600 miles long—which would cover the distance to the sun 1½ times, or nearly a quarter of the earth's orbit. Again, it would make a flame having a width of one mile that would encircle the earth.

If it could be converted into energy through the agency of a gas engine, 1,094,723,036 horse power would be developed, which would be capable of raising 36,125,360,221,000 pounds 1 foot high in a minute of time; or would raise one pound 6,842,018,975 miles in one minute of time; or would project a ball, weighing 74 pounds, into the sun in a similar period of time. If it were possible to obtain the velocity which would be the result of this projection, it would equal 1,533.333 miles per second, or about three times greater than the velocity of light, which is reckoned at 182,000 miles per second.

Companies to the number of 295 remain to be accounted for, 723 having been considered in the foregoing estimates. Placing the annual output of the 295 companies at one half the average of the companies we have considered, we see it will equal about 4,913 372,000 cubic feet, which, at \$1.75 per thousand, possesses a money value of \$8,600,000. Now, the 24,083,906,000 cubic feet output of the 723 companies was worth \$42,447,812.25, and adding thereto the estimated output of the 295, we have a total make of 28,997,528.800 cubic feet, with a value of \$51,047,812.25.

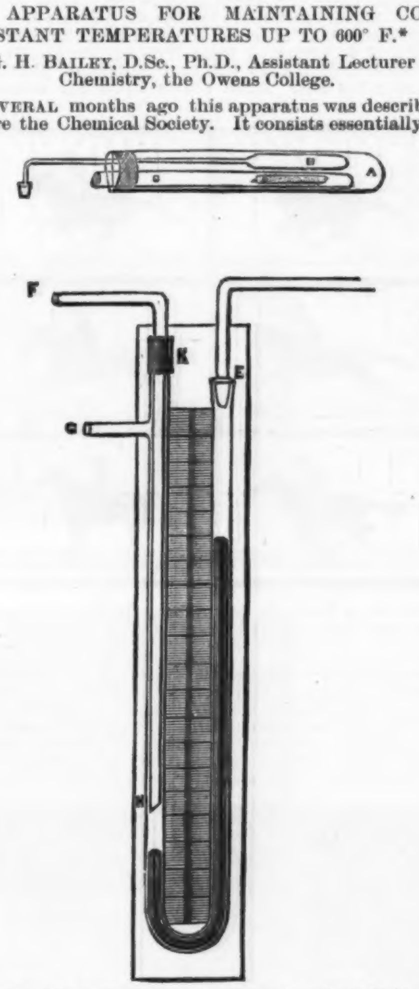
In order to give some further idea of the magnitude of the business, I have placed the capital required to carry on this vast enterprise at \$9 per 1,000 feet of output, which will equal about \$261,065,502, or nearly \$5 for every man, woman, and child in the country. Certainly, these figures show somewhat of the vast magnitude of the business in which we are engaged, and entitle us to more consideration than we receive at the hands of those we are trying to serve by untiring efforts to give them good and cheap gas, and the benefit of all improvement that helps to cheapen its manufacture. We often hear people talk of the outrageous imposition of gas companies in charging exorbitant prices for gas. If the figures herewith submitted do nothing else, they certainly disprove that charge.

In conclusion, I trust my humble efforts have demonstrated to you that we have a business possessing a magnitude greater than any of you supposed—it certainly exceeded my ideas; further, that it is one we may well be proud of, and is worthy of our best efforts to perfect in every possible way.

AN APPARATUS FOR MAINTAINING CONSTANT TEMPERATURES UP TO 600° F.*

By G. H. BAILEY, D.Sc., Ph.D., Assistant Lecturer on Chemistry, the Owens College.

SEVERAL months ago this apparatus was described before the Chemical Society. It consists essentially of



NOTE.—The upper figure is drawn to only half the scale of the lower.

a furnace (not shown in the figure) of six Bunsen burners, a heating tube, an air thermometer (so arranged that the temperature may at any time be estimated), and a regulator by which the temperature may be limited and kept constant. These parts will be described in the order given.

The heating tube (A) is of combustion glass, closed at one end; it is 25 cm. long and 4 cm. in diameter, and is placed horizontally within an iron casing over the furnace. Within this is the heating tube proper (C), into which the substance to be heated is introduced in a platinum boat (D), while alongside this tube is the bulb (B) of the air thermometer.

In order that the temperature, as indicated by the air thermometer, may as nearly as possible correspond with that of the substance heated, the inner tube and air thermometer are arranged along the horizontal diameter of the outer tube, and this latter is separated from the iron casing by an air space. In point of fact it is found that the variations of temperature do not exceed 2 or 3 degrees. The bulb of the thermometer is connected, by means of a capillary tube, with a U-tube (E), the near limb of which is in the first instance filled with mercury, while the further limb contains a column of 3 or 4 cm. As the heating proceeds, the column of mercury in the near limb of the U-tube is depressed, the amount of the depression being a measure of the temperature; indeed, the instrument may be graduated by noting the temperature on a high-boiling thermometer placed in the heating tube, and the reading of the mercury column on the millimeter scale attached to the U-tube. The further limb of the U-tube answers as regulator, and by it we are enabled to limit the temperature to any desired degree. This is done by causing the gas supply for the furnace to pass through the tube (F, H), and out at the side tube (G). At H, the tube is cut off slantwise, and perforated with a small hole a little above the outlet, as in an ordinary gas regulator. As, then, the column of mercury is depressed in the near limb of the U-tube, it rises in the further limb, ultimately reaching the outlet (H), and partially cutting off the gas supply. It is evident, therefore, that if the outlet of the regulator is only a short distance above the mercury, this point is soon reached, and a low limit of temperature (say 100°) is attained. The temperature can be kept at this point for any period desired. Then, by raising the regulator somewhat (and this is easily done, since it slides in the India-rubber connection, K), a higher limit (say 120°) can be attained, and so on up to 600°, beyond which no trial of the apparatus has been made.

In order to prove that the apparatus is reliable, the author has determined a number of melting points with it. He has also calculated the temperatures from the known volume of the air thermometer bulb, according to the law of expansion of gases.

An attempt to control the higher temperatures by Siemens' electrical method, though it showed general agreement, cannot be said to have confirmed the observations with any definiteness, since in this method so much depends on the particular character of the platinum used.

The immediate purpose for which the apparatus was designed is the determination of the atomic weight of those elements in which it is necessary to employ the normal sulphate, and the author is of opinion that by the use of such means the determination from the sulphate may attain a much higher degree of accuracy than heretofore. The normal sulphate will be heated at successive temperatures until decomposition begins to set in, this point being indicated by aspirating a current of air through the heating tube after each period, and passing it through a solution of barium chloride.

Having determined the lowest temperature at which decomposition occurs, the sulphate is then heated with excess of sulphuric acid, and that point determined at which it loses all free sulphuric acid; and these temperatures having been ascertained once for all, it is only necessary in further experiments to heat the sulphate (with excess of sulphuric acid) at some temperature lying between these limits until constant.

As the process can be watched and the products of decomposition collected and examined, it is hoped that the apparatus may prove useful in examining the general phenomena of decomposition of salts by heat.

* A paper read before the British Association, Birmingham meeting, Section B.—*Chem. News.*

PHOTOGRAPHY OF MOVING OBJECTS, AND THE STUDY OF ANIMAL MOVEMENT BY CHRONO-PHOTOGRAPHY.*

By E. J. MAREY.

MOTION is an essential attribute of life; it is the most apparent, if not most easily understood, manifestation of it. In the body of a living being motion exists everywhere; the blood circulates, the heart beats and arteries pulsate, the lungs alternately fill with air and empty themselves. Every organ undergoes alternative variations in volume; rhythmic movements of expansion and contraction are connected with the intermittent flow of blood as it traverses them. The muscles continually vibrate under the influence of the motor nerves. In fine, there is not one element of the organic tissues which, in its evolution, does not change its form, its volume, and its position. Thus, weak or strong, slow or rapid, motion prevails in all the parts of living beings.

Besides these internal or organic movements, sometimes so slight that our senses cannot perceive them, there are others, entirely external, rapid, extended, energetic. These are the movements of the subjective life; such are the locomotion of man, the different gaits of quadrupeds, the flight of birds, etc.

While the organic movements are often concealed by their slight extent or their slowness, those of animal life escape observation by their greatness, suddenness, variety, and complication.

The duty of the physiologist is to invent all sorts of artifices to render visible these different movements, and determine rigorously their character. I have spent many years in seeking for methods, in inventing or in perfecting apparatus designed to measure organic movements. I still pursue my task, and to-day endeavor to introduce exactness into the analysis of the movements of man and of different species of animals.

Whatever movement is to be studied, it can only be expressed in one satisfactory manner. It is to give its figure or its graphic expression. In the simpler cases the movement transmitted to certain apparatus is automatically recorded on a piece of paper uniformly unrolled. A curve is thus obtained whose sinuosities express changes in direction or in velocity, in other words, all the phases of movement.

Inscribing or registering apparatus are now too numerous and too well known for me to enumerate them or explain their use. It will suffice for me to show you the curves given by the pulsations of the arteries to prove how fully the registration of these movements reveals delicate shades of difference that escape recognition by the most skillful touch.

Fig. 1 shows several pulse curves obtained by the sphygmograph. The examples are at random. The extreme variations can be seen at a glance. By a similar process the trace of the beats of the heart of a man are obtained by applying a special instrument to the part of the chest where the heart movements are most easily discernible. In these curves the variations are greater than in those of the pulse. Every inflection shows some functional phase. Physiologists and physicians have learned the functional or clinical meaning of most of the forms. Of all these registering apparatus, it may

* A paper read before the French Association for the Advancement of Science, at Nancy (1886).

be said that they express in a complete manner movements that direct observation can only imperfectly reach.

For the analysis of the movements of the external or subjective life, registering apparatus has a very limited scope.

You can easily imagine the difficulties encountered in

FIG. 1.—Sphygmographic traces of the pulse in different patients. These types are taken at random, merely to show the variety of graphic forms.

imparting to fixed apparatus the movements of a body that changes position, and to reduce these movements when too extended, too violent or too rapid, as in the case of a running quadruped or flying bird. Some attempts had already given important results.

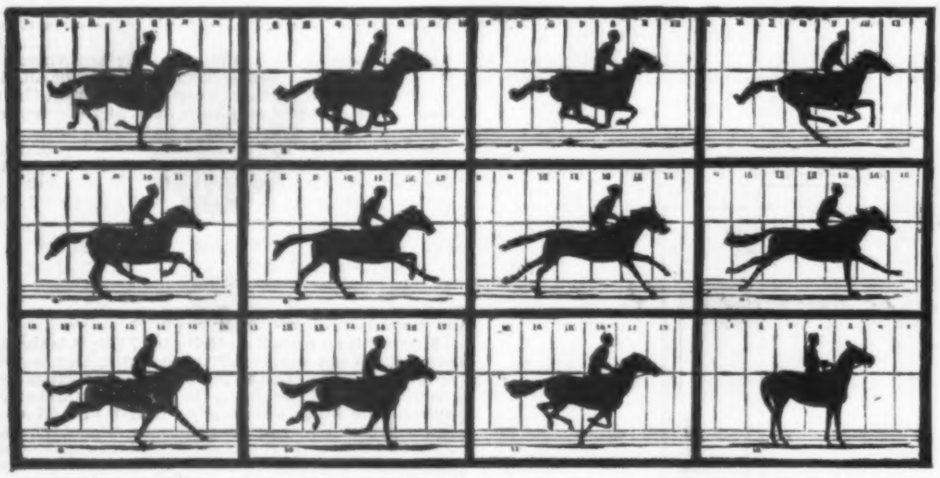


FIG. 2.—Twelve successive photographs, by Mr. Muybridge, of a horse in full gallop. In the last figure the horse is shown standing still. The speed of the horse was about 1,142 meters (3,746 feet) per minute.

Thus I have obtained from large birds the curves of wing movements during flight, and caught the rhythmic beat of each foot of a horse in different gaits. Again, one of my students, now himself a master, Professor Carlet of Grenoble, has inscribed with great precision certain movements of the body and limbs of a man walking.

FIG. 3.—Arrangements adopted by Mr. Muybridge in his experiments on the gaits of a horse. On the left is the reflecting screen against which the animal appeared *en silhouette*. On the right is the series of photographic apparatus of which each one took an image of the animal.

But for the complete study of the movement of man and animals, mechanical methods of inscription must give way to another application of the graphic method more simple and perfect, because it inscribes the movements without impeding them in any way. I refer to chronophotography.

A long period has passed since our learned physicist and astronomer Janssen, by a species of intuition, prophesied that photography would sooner or later supply the means of analyzing the movements of animals. A skillful photographer of America, Mr. Muybridge, in part solved this problem by brilliant experiments. I wish briefly to describe his method of work.

Mr. Muybridge arranged one after the other a range of photographic instruments facing a white screen, be-

FIG. 4.—Stereoscopic image of the movements of a brilliant ball carried on the head of a walking man.

fore which passed an animal walking, trotting, or galloping. As fast as the animal advanced, the shutters of the lenses opened and permitted the taking of a negative of the animal. These views differed from each other, because they were taken in succession. They showed, therefore, the animal in the various attitudes which he had assumed at different instants during his passage across the field covered by the instruments.

Fig. 2 is borrowed from Mr. Muybridge. It shows a horse galloping, in different phases of placing and raising his feet. Lines drawn upon the screen, and numbered, show how far the animal moved between successive images. Fig. 3 shows in detail the installation of Mr. Muybridge's apparatus. To the left is the inclined screen, which throws into the cameras a dazzling white light, bringing out *en silhouette* the body of the animal. On the right is the range of cameras, each one provided with a shutter actuated by a powerful spring, so arranged as to expose the objective for an extremely short time, estimated by the author as one-fifth of a second. To insure the successive opening of these shutters as the animal advances, threads may be observed stretched across the road. The animal breaking these threads one after the other opens an electric circuit, and causes the successive springing of the different shutters.

Mr. Muybridge varied his experiments most skillfully. He studied the gaits of different animals and those of man, jumping, vaulting, and handling of various utensils. Finally, he collected in a voluminous album an interesting series of attitudes of men and of animals in motion. The whole collection of these studies possesses great interest for artists.

Since this time the progress of photographic chemistry has wonderfully increased the sensibility of the plates, and at the present day more than mere silhouettes of moving animals or men can be obtained. In

FIG. 5.—Chrono-photographic trajectory of a brilliant ball thrown across the black screen.

good light, full images, with all desired relief, can be obtained. If, for example, a naked man in motion is photographed, all the muscles of the body are perfectly traced in relief, indicating the part taken by each of them in the movement executed.

The silhouettes obtained by Mr. Muybridge would always suffice to illustrate the successive phases of displacement of the members if they were taken at equal intervals of time; but the arrangement adopted for bringing about the formation of the successive phases causes irregularities in the extent of these intervals. The threads yield more or less to the stress before breaking, and, moreover, the progress of the horse is not at an even rate of speed. Nevertheless, Mr. Muybridge endeavored to develop from the series of images the trajectory of each leg of the horse; but the curves obtained in these laborious attempts had not sufficient precision. A very simple method enables us to obtain with perfect fidelity the trajectory of a

FIG. 6.—Loops and nodes formed by successive positions of a long flexible rod to which are imparted vibratory motions.

body in movement. It is the photographing of this body in front of a black surface.

If a photographic apparatus is directed against a black screen, the objective can be uncovered without effect on the sensitized plate, as it will receive no light. But if across the plane of and parallel with this screen a white ball, strongly illuminated by the sun, is thrown, the image of this ball will be reproduced upon the plate, which, on developing, will show the trace of the ball in its trajectory, just as with those lines of fire of which our eye receives a momentary impression when a lighted piece of charcoal is waved through the air at night.

But the movement of a body in space is not always confined to a plane like that of a projectile. The body can be displaced in all three dimensions of space. To show the inflections of a trajectory in all directions, recourse must be had to stereoscopy. The images shown

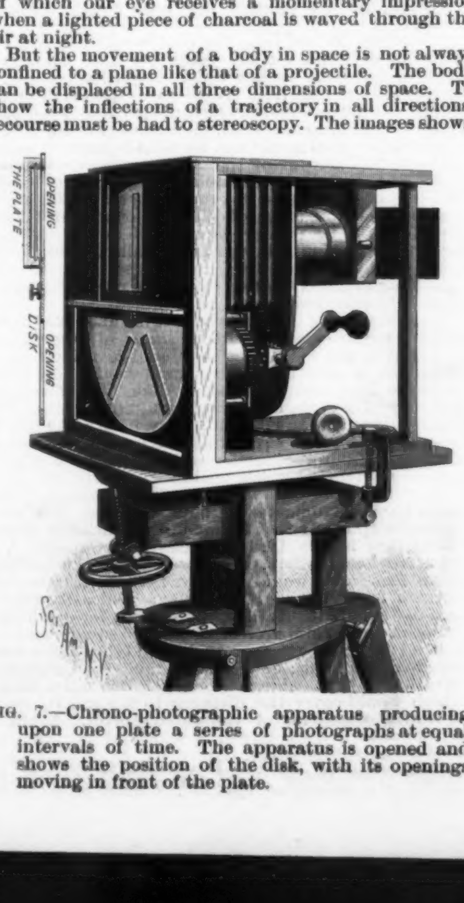


FIG. 7.—Chrono-photographic apparatus producing upon one plate a series of photographs at equal intervals of time. The apparatus is opened and shows the position of the disk, with its openings moving in front of the plate.

in Fig. 4 are thus obtained. Taken at different angles, they produce when seen in the stereoscope the appearance of relief. These trajectories show the movement of the head of a walking man. The displacement is in all three directions, because, in addition to his lateral

FIG. 8.—Walking man, clothed in white, passing across the field.

and vertical moments, the man is continually progressing.

Photography against a black background is invaluable for determining the points in space passed over by a body in movement. No other method can express the line followed by a luminous point in darkness. Quite recently, M. L. Soret, of Geneva, has used this method in analyzing very complicated movements. Working

FIG. 9.—Successive attitudes of a runner. The interval between two consecutive images is one-fifth of a second; the time of exposure, one two-thousandth.

FIG. 10.—Jumper leaping over an obstacle.

in darkness, he photographed the trajectories of an incandescent lamp under various movements.

Stereoscopic or plane, these figures furnish only an incomplete idea of motion. They only give the idea of place, and not that of time, which is indispensable, as movement is only the relation of space to time. To fully comprehend the movement of a thrown stone, it is necessary to know what points of its parabolic trajectory were occupied by this stone at successive periods, equally distributed, as, for example, at the intervals of fiftieths of a second.

To obtain this noting of time it is enough to shut off at equal intervals light from the photographic appara-

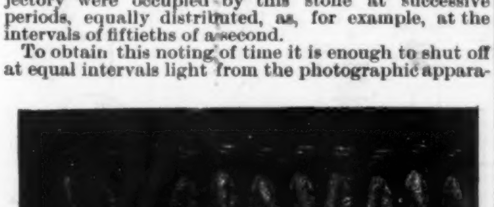


FIG. 11.—Slow walk; the images by superimpositon tend to confusion.

tus. This interruption may be produced by a rotating opaque disk, pierced with small apertures, which only permit light to reach the sensitive plate intermittently.

Fig. 5 is the parabolic trajectory of a brilliant ball thrown across the face of the dark screen, but the trajectory is discontinuous, as the exposures were only produced each fiftieth of a second, on account of the number of openings and speed of rotation of the disk.

In most experiments, a rule two meters ($78\frac{7}{10}$ inches) high, situated in front of the screen, produces its own image upon the plate, and serves as a scale, so that the paths of the projectile during each fiftieth of a second can be estimated in actual value, at different places of its course. Thus it can be seen that the speed of the projectile diminishes in the ascending limb of its parabolic trajectory, and increases in the descending one. This method, which I have designated *chrono-photography*, shows the complete law of the movement of a body in space.

If the memorable work of Galileo and of Atwood had not revealed the law of the motion of bodies falling under the influence of gravity, it would suffice to throw a stone up in the air and take its trajectory by chrono-photography to discover this law; just as in Fig. 5 would be obtained the uniformly varied movement of this stone, along with the actual value of the accelerations shown in equal succeeding periods.

We may wish to know how a long wooden rod acts when shaken by one hand and held firmly by the other. Fig. 6 shows the loops and nodes of the vibrations on different parts of the rod. If the position of the hands is changed and brought nearer the end of the rod, the form of the vibrations instantly changes.

Thus it is evident that a limitless number of varieties of movement can be analyzed by chrono-photography.

All the figures studied by geometricians, and which they imagine as generated by the rotation of curves, the translation of lines, and the intersection of planes, all these figures, I repeat, can be actually produced in chrono-photography, by successive images of these curves, lines, and planes that are displaced.

The sharpness of the images depends on the shortness of the time of exposure corresponding to each position. It is, in fact, necessary that the body in motion shall not have time to be sensibly displaced while its photograph is taken. The time of exposure therefore which I have selected is the one-thousandth of a second. I sometimes use less, for, as regards certain very rapid movements of the wings of birds, this period is too long. In recent experiments I have got good results with exposures of one two-thousandth of a second.

Doubts have been expressed as to the reality of these short times of exposure, and with ordinary shutters it would be quite difficult to attain this quickness; but the perforated disk that is used in chrono-photography

gradually acquires a speed of rotation that may be very great. Fig. 7 shows the arrangement of this disk, to which a rotary movement is imparted by powerful gearing, controlled by a regulator. As soon as the disk attains a speed of ten turns a second, the regulator maintains this speed with perfect uniformity, with chrono-photography in addition as a control. The disk moves in front of the sensitive plate a few millimeters (1 mm. = 0·039 in.) distant from it only. Then, knowing the angular value of each of the openings, the period of exposure is rigorously deduced therefrom.

The condition most difficult of fulfillment is the absolute darkness of the screen before which we operate. Little light as this screen may reflect upon the sensitive plate during a single exposure, these small quantities of light, accumulating their effect over the whole surface of the plate, end by fogging it completely. A wall painted with any black pigment, velvet even, exposed to the sun, reflects too much light for a plate to withstand, that is of sufficient sensibility to receive at different points a long series of successive images. Thus the term black screen is used metaphorically. The work is done before a dark cavity.

In his remarkable studies of colors, the illustrious

FIG. 12.—Man clothed in black velvet, on which the axes of the limbs are traced by white cords; the joints carry white buttons placed at the point of rotation. The head is covered by a helmet of black velvet, which completely hides it and to which is affixed a bright ball at the level of the ear.

Chevreul showed that, to obtain absolute black, it was necessary to pierce a hole in the side of a box blackened interiorly. Placed by the side of this dark opening, a piece of fabric, or any material substance, black as it might be, appeared only of a dark gray. It, therefore, reflected some white light.

To obtain favorable conditions, a great chamber, of ten meters (33 feet nearly) depth, and of equal breadth, was constructed. One face of this chamber is open, and restricted by movable frames to the exact height necessary. The interior of the chamber is completely blackened, the ground is coated with pitch, the back is hung with black velvet. In front of this long band of darkness passes a railroad, carrying the photo-

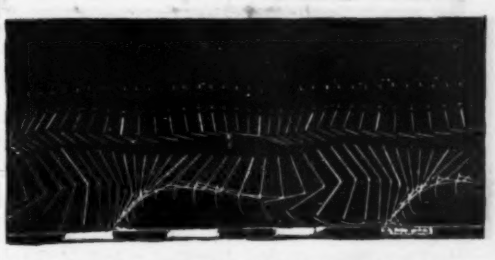


FIG. 13.—Chrono-photographic images of a runner. Below the figure is a scale whose divisions are 0·50 meter ($19\frac{7}{10}$ inches) long, and serve to give the extent of the movements.

graphic apparatus, which is brought nearer to or further from the screen, according to the size of the images desired.

Against the dark field just described, a man, placed in full light, naked or clothed in white, gives a sharp image on the sensitive plate (Fig. 8).

Fig. 9 shows a runner in four succeeding attitudes. The shutter disk employed had only a single opening, and as it made five turns per second, the interval separating two consecutive images corresponds to the distance passed over in one-fifth of a second; the time of exposure for each image being always one two-thousandth of a second. Just as in the case of the brilliant ball, we can follow the movement of the runner and estimate his speed by the space passed over between two successive exposures; it may be two meters (6 feet 6 inches) or ten meters (33 feet nearly) per second.

If the rate of running was slower, the number of images would increase, for the space passed over in one-fifth of a second would be shorter, and the images, consequently, would be closer to each other.

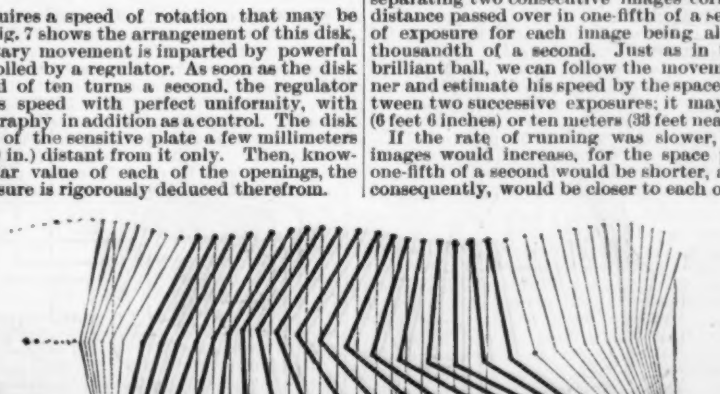


FIG. 14.—Oscillations of the leg of a walking man.

In the jump, Fig. 10, curious attitudes are seen, assumed by the body at different instants. The first effort, the impulse given by a single leg, the movement of flexure that raises the feet as the object is passed over; finally, the descent, accelerated according to the laws of falling bodies, the easing of the shock by the gradual bending of the legs, and, finally, the return to an upright position. Even in this figure the images become superimposed at the moment when the motion of the body is reduced, as at the end of the descent. This confusion is still more perceptible in a slow walk (Fig. 11), where the images of the legs are hard to disentangle. And yet the number of the images is only five per second—insufficient to give a complete idea of the series of movements executed.

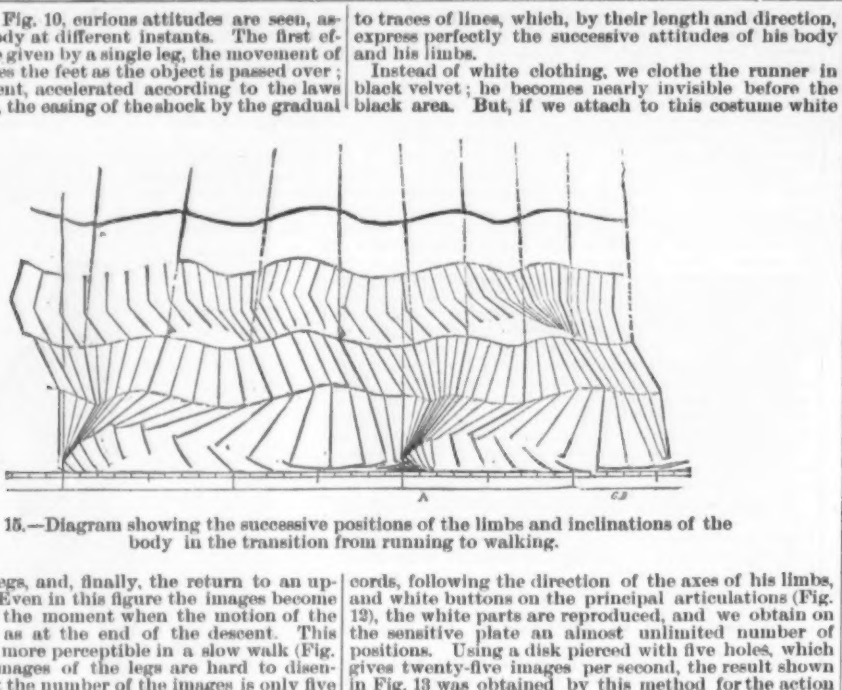


Fig. 15.—Diagram showing the successive positions of the limbs and inclinations of the body in the transition from running to walking.

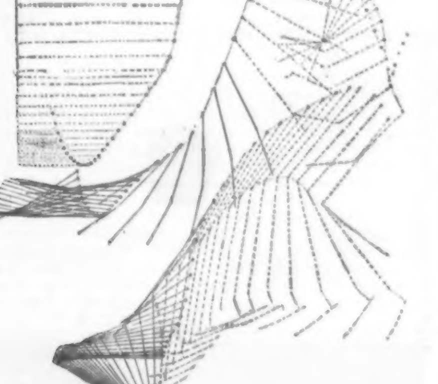


Fig. 16.—Successive positions of the limbs in an elastic jump upon the ball of the foot.

Have we, then, reached the limits of chrono-photography? A very simple artifice relieves us from the difficulty.

In the experiments first described, a ball of the size of a billiard ball gave, without confusion, as many as fifty images in a second; a rod as thick as the finger showed perfectly its vibratory movements. It was because the images had a surface of small extent, and the least motion of translation separated them from each other. If we reduce, or, rather, suppress, the surface of the man experimented with, we can multiply indefinitely the number of his successive attitudes.

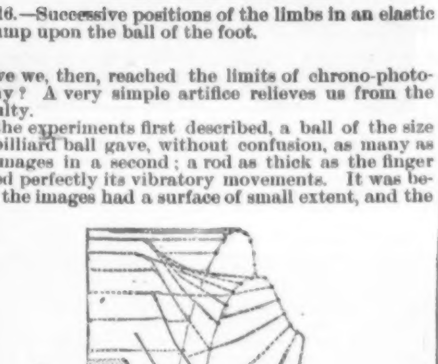


Fig. 17.—Inelastic jump upon the heels.

We shall now see how the image of a man is reduced to traces of lines, which, by their length and direction, express perfectly the successive attitudes of his body and his limbs.

Instead of white clothing, we clothe the runner in black velvet; he becomes nearly invisible before the black area. But, if we attach to this costume white cords, following the direction of the axes of his limbs, and white buttons on the principal articulations (Fig. 12), the white parts are reproduced, and we obtain on the sensitive plate an almost unlimited number of positions. Using a disk pierced with five holes, which gives twenty-five images per second, the result shown in Fig. 13 was obtained by this method for the action of running, which shows in full detail the movements of the left half of the body—head, arm, and leg. We must observe that every fifth image is a little stronger than the others. This is effected by making one of the apertures in the disk larger than the others. The time of exposure is thus increased, and the intensity of the image is greater. The object of this disposition is to furnish base marks, by means of which it is always easy to recognize traces corresponding to the same image, that is to say, to a given attitude of the runner.

This figure, we have said, only shows the movements of the left half of the body. But in a symmetrical gait, the two halves of the body repeat, alternately, the same acts. So that two transparent representations, such as those above, will give the complete expression of all the runner's movements, provided that, in superimposing them, one picture is moved along over the other, so as to cause the due alternation of the points of rest of the left and right feet.

Thus partial chrono-photographs give the complete expression of the law of movement of each part of the body. As in the trajectory of projectiles, here we can see for each point taken by itself the curve it described, and its accelerations and retardations at different phases of the gait. By projecting on a screen the magnified photographic images, so as to give to the runner his true dimensions, the absolute value of the space passed over in known times, and, in consequence, the velocities, accelerations, and retardations of these points, are obtained.

In the detailed studies, a part of the images is screened, as is done in Fig. 14, for the purpose of analyzing the oscillations of the leg in walking, or, as in Fig. 15, with rule or dividers, there are traced construction lines to give better expression to the inclination of the limb or trunk referred to the vertical.

These diagrams are very well adapted for the comparison of two sorts of movements whose difference cannot be discerned by the eye. Thus, in jumping from an elevation, the shock of the feet against the ground is reduced in intensity by bending the legs while the extensor muscles operate to sustain the weight of the falling body.

Figs. 16 and 17 show two sorts of jump. The first with flexure of the legs and reduction of the shock, the second with the legs almost straight, which implies a severe shock of the feet against the ground.

(To be continued.)

THE NEW SEXTUPLEX TELEGRAPH.

The multiplexing of telegraph lines has been effected in several ways, says the *Electrical World*, among them being the methods of compensation and neutralization, as in the duplex and quadruplex; the method of synchronism, as in the Delany and Callahan system; and also the method of harmonic telegraphy, such as that devised by Gray. We might also mention the increase of the capacity in lines effected by the methods of simultaneous telegraphy and telephony over the same wire.

In the new sextuplex telegraph system of Mr. Stephen D. Field, while some methods are employed analogous in some cases to those used in the systems above mentioned, the system as a whole is decidedly novel and interesting, and, judged from the results of its practical operation which we recently had occasion to witness, is destined to an early application.

Mr. Field has started out with the well-known fact

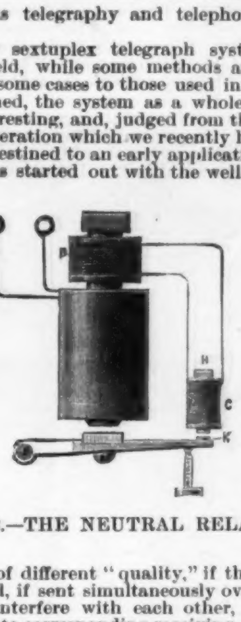


Fig. 2.—THE NEUTRAL RELAY.

that currents of different "quality," if the expression may be allowed, if sent simultaneously over the same wire, do not interfere with each other, and can be caused to operate corresponding receiving instruments at the other end of the line. Thus in the new system three different qualities of current are employed, viz., a direct current of increasing and decreasing strength, operating a neutral relay; a reverse current, operating a polarized relay; and a rapid vibratory current, which sets a telephonic diaphragm in rapid vibration. These three currents acting upon corresponding receiving instruments, do not interfere with each other, as will be shown below; and as each one type of working is duplexed by the well-known compensating method, the line is evidently capable of transmitting three messages in either direction, or six simultaneously.

The arrangement of circuits and apparatus by which these results are effected is shown in the accompanying diagram, Fig. 1. We may remark at the outset that not a single cell of battery is employed for any pur-

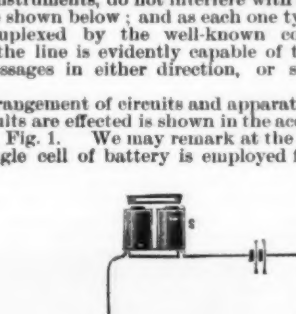


Fig. 3.—THE VIBRATORY RECEIVER.

pose, both the main line and locals deriving current from a dynamo. The latter is shown at F, and the armature, as will be seen, is provided with two independent sets of windings, which deliver current respectively to the commutators, E and D. The local currents are taken off the commutator, E, the circuit connecting with the three local transmitters, 1, 2, and 3, which are manipulated in the ordinary way by the keys, K', K², K³. The main current is taken from the armature from the commutator, D, this current serving to actuate the neutral and polarized relays which are shown diagrammatically at 2' and 1' respectively. It will be noticed that the dynamo, F, is shunt wound. Its armature is of 150 ohms resistance, and it has an E. M. F. of 300 volts at 500 revolutions. The shunt

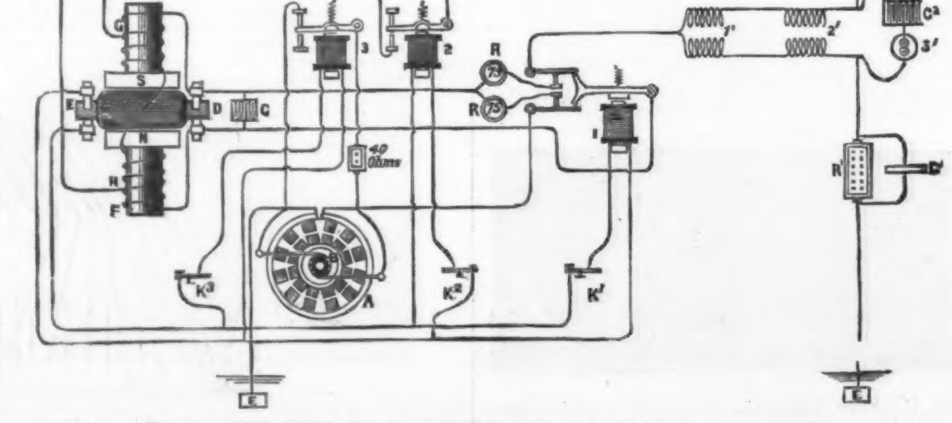


Fig. 1.—THE NEW FIELD SEXTUPLEX—DIAGRAM OF CIRCUITS.

coil is divided so as to give a long and a short shunt at the points, G, H, depending upon whether the transmitter, 2, be closed or open. The resistance of the short shunt is 540 ohms, and that of the long shunt is 6,000 ohms. Hence it follows that by pressing K², the armature of transmitter 2 is attracted to the front stop, and short-circuits the long shunt of the dynamo. This, of course, causes an increase of current in the short shunt, the strength of the field magnets remaining constant; and hence there ensues a decreased effect in the line current, and it is upon this increase and decrease of the direct current that the neutral relay, 2', operates. We will not for the present enter into a description of this relay.

Transmitter 1 operates a pole changer, by which reverse or alternate currents are sent over the line, which actuate the polarized relay shown diagrammatically at 1. The pole changer is so adjusted as to be continuity-preserving as regards the line, but with a very slight break toward the dynamo.

It is evident that the continuous current designed to operate the neutral relay has no effect upon the polarized relay; but the reverse currents designed for the latter would affect the neutral relay if some provision were not made to prevent this disturbance. This has been recognized by Mr. Field, and he overcomes the difficulty in a very simple manner.

The neutral relay, 2, is shown in part perspective in Fig. 2. To understand its operation, we will premise that when ordinary reverse currents are sent through a neutral relay, the armature is kept in a state of vibration, breaking contact momentarily at each reversal, but being immediately reattracted. With the arrangement of the neutral relay shown in Fig. 2, the reverse current has no effect on the armature. This result is obtained by taking advantage of the induced currents generated by the reversals. As will be seen, the core of the relay is lengthened, and has a bobbin, B, surrounding it. The latter is connected to another small bobbin, C, surrounding a core, H, which is placed opposite a small cylinder of iron, K, acting as an armature and attached to the lever of the relay. The reversal of current in the relay bobbin causes a change of polarity in the core, and the tendency is to momentarily throw off the armature; but at the same instant of the reversal of polarity an induced current is set up in the bobbin, B, which is in opposite direction to the primary, and which, in circulating through C, tends always to magnetize the core, H, oppositely to that of the main core, and hence with a corresponding influence upon the small armature, K. The result of this is evidently that with two opposite influences acting upon the lever, it will remain stationary and insensible to the effects of the reverse currents.

We come now to the third and last method employed in transmission, which consists in sending a rapidly vibrating current over the line, which is made to set a telephonic diaphragm in vibration.

The source of the vibratory current is the small dynamo, shown at A. From the arrangement of circuit, S, it will be seen that the commutator, B, cuts the line coils of the vibratory magneto, that is, the outer ring of magnets, out of circuit, except at the instant of passage of the poles, and thus reduces the resistance of the circuit from 160 to 5 ohms, which changes evidently occur in continuous rapid succession, sending a vibratory current over the line. These currents charge the condenser, C³, at the distant station, which tends to increase heir abruptness, and thence pass into the vibratory receiver or relay, 3¹. The latter is shown in detail in Fig. 3. It consists of a horseshoe magnet, M, upon which are mounted the coils, F, through which the vibratory current from the line is made to pass. Opposite the poles of the magnet is placed the diaphragm, D, which has a platinum pin, C, mounted on its center. Resting upon this pin is another, B, which is attached to the end of a lever which, together with the diaphragm, D, is in circuit with a sounder, S. A local battery is here shown in circuit merely for the sake of clearness, the current being in reality taken from the local leads of the dynamo.

Now, when the key, K³, is open, the armature of the transmitter, 3, is on its back stop, and closes a circuit including a 40 ohms resistance, so that the current from the vibratory generator is short-circuited and does not go out over the line. When the key, K³, is depressed, however, the armature of 3 is attracted, breaks the short circuit, and the vibratory currents then pass out to the line. Arriving at the receiver, shown in Fig. 3, they set the diaphragm, D, in rapid vibration, so that the pins, B and C, are given a rapid make and break motion. In fact, so rapid is the motion, and so short a time are the pins in contact, that the local circuit is practically open and the sounder has not time to act, being purposely made sluggish in its movements. The local circuit remains open, then, as long as the key, K³, is depressed. The dots and dashes of the key are therefore received on the vibratory receiver as a series of "buzzes," which are transformed in the manner described into dots and dashes on the local sounder, S.

Both the relays as well as the vibratory receiver are wound differentially, as in the ordinary duplex service. The action is very smooth, and ordinary changes of condition of the line do not affect the working. The static capacity of the line at the time of our examination of the apparatus, when increased from that of a few miles to that of a line over 400 miles in length, required only a slight readjustment of the vibratory receiver.

GRAY'S STANDARD GALVANOMETER.

THE idea of using an infinitely long solenoid for the production of a uniform magnetic field has already been often suggested, either for the purpose of constructing a standard galvanometer or for various experiments in absolute measurement.

Mr. T. Gray has recently constructed a standard galvanometer, in which he uses a very long bobbin for the production of a constant magnetic field, and which in form is like a sine galvanometer. As well known, the great difficulty with the tangent galvanometer is the accurate determination of the mean diameter. In the Helmholtz combination, there is also the distance of the mean planes to be measured.

In the arrangement employed by Mr. Gray, the radius figures merely as a corrective term, and less of an approximation suffices.

In a bobbin whose length is considerable with respect to the diameter, the field produced per unit of current is, in the axis,

$$F = 4\pi n \frac{1}{\sqrt{r^2 + l^2}}$$

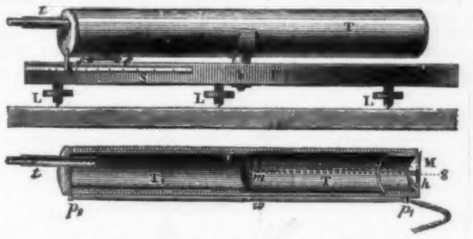
where n is the number of revolutions of the wire per unit of length, and l the half-length of the bobbin. We may put this expression in the form of

$$F = 4\pi n \left(1 - \frac{r^2}{2l^2} + \frac{r^4}{\gamma l^4} - \ . \ . \ . \right)$$

For a relation $\frac{l}{r} = 10$, for example, it suffices to employ the second term of the series, which gives a correction of 1-200. What it is necessary to know accurately is n. We know the total number of revolutions, $2nl$, and can measure l to 1-10 of a millimeter. With a one meter bobbin we can therefore calculate n to within nearly 1-10000. But it is necessary that the winding of the bobbin shall be perfectly uniform, and this may be effected by means of a lathe.

With this apparatus, we shall have a greater resistance for the same sensitiveness; but this is not of much consequence in a standard instrument. This bobbin might be used as a tangent or sine galvanometer, and Mr. Gray prefers to give it the form of the latter.

The accompanying figure shows the instrument as he constructs it. The tube, T, which carries the wire (a



GRAY'S STANDARD GALVANOMETER.

single layer) is mounted upon a platform, P, provided with leveling screws, and capable of revolving around a vertical axis, V, the rotations being read upon the scale, S. The tube, t, is capable of sliding in the interior of T. At its extremity, which corresponds to the center of T, there is a plane mirror, m, and a small magnet, A, suspended in the axis. At s, at the extremity of T, there is a small scale which is illuminated by a ray of light passing through the aperture, h, and reflected by a prism or an inclined mirror. Above s there is a plane mirror, m. The image of s is reflected first by the mirror, m, and next by M. The readings are made with the telescope, t, placed at the other extremity of the tube, T.

One of the extremities of the bobbin wire is fixed at p, and the other, p^1, is connected, through the wire, n (parallel with the axis), with a pin, p^2, near p^1. The conductors, which are twisted together, end in terminals placed upon the base, P.

The instrument operates as follows:

The bobbin is so arranged that the central mark of s shall coincide with the reticule of the telescope, and the position of the index on the scale, S, is then noted. The current now being allowed to pass, we note the rotation necessary to bring back the center of s on the reticule. Then we reverse the current and displace the scale, S, so that the rotations shall be equal on both sides. When this has been brought about, we have the relation

$$I = H \sin \vartheta \times \frac{1}{4\pi n \left(1 - \frac{r^2}{2l^2}\right)}$$

It will be possible to read the rotation ϑ very accurately by means of microscopes and verniers.—*La Lumiere Electrique.*

THE COLORS OF METALS AND ALLOYS.*

By Prof. W. CHANDLER ROBERTS-AUSTEN.

THIS lecture is published by request, but the author fears that, dealing as it does with the colors of metals, such interest as it may have possessed when delivered will be greatly diminished in the absence of the experiments and diagrams by which it was illustrated.

I begin with no ordinary pleasure the work which has been intrusted to me by the Council of the British Association. It is nearly twenty years since this series of lectures was established. The first, on "Matter and Force," was delivered at Dundee, by a brilliant experimenter and one of the most eloquent living exponents of science. It was followed, at Norwich, by a lecture by Prof. Huxley, to whom the nation owes a deep debt of gratitude for his intense sympathy with all who are seeking to widen the bounds of scientific knowledge—to be whose colleague in one of the most important scientific schools of the country is my great good fortune. These lecturers were succeeded by other eminent men, among whom may be mentioned Spottiswoode, Bramwell, and Lubbock. The object of the lectures is to diffuse a knowledge of the operations of nature, and to add to the number of those who rejoice in her works. Many, therefore, who have spoken to audiences similar to this, have appealed to natural phenomena; and instead of talking to you about the color of metals, I also should have liked to dwell on the color of the sea and sky, but Ruskin's works are, I know, often in your hands, and he has told you once for all of the color of clouds that "there is not a moment of any day of our lives when nature is not producing scene after scene, picture after picture, glory after glory, and working still upon such exquisite and constant principles of the most perfect beauty that it is quite certain it is all done for us, and intended for our perpetual pleasure."* The metallurgist, however, cannot speak with authority on themes such as these; and I have, therefore, selected a subject which will, I believe, enable me to bring before you important truths affecting a wide range of industrial operations, and at the same time to sustain the true function of art by pointing to the direction in which we may have increased pleasure in things that constitute our most ordinary possessions, and which we use in daily life.

First permit me to explain that I intend to include under the title of the lecture any facts which are, in my opinion, connected with the colors of metals and alloys, whether natural to them or produced by artifice, as well as a brief examination of the influence which the colors of metals appear to have exerted on the history of science.

I propose to begin at what will appear to be a somewhat remote starting point. We say that copper is red, gold yellow, and silver white, but it is by no means certain that the early races of the world had any very clear perception of the difference between these several metallic colors. With regard to early Hebrew and Greek civilization, Mr. Gladstone has expressed his belief that the color sense—that is the power of recognizing color and distinguishing it from mere brightness or darkness—was imperfectly developed, and he considers that "the starting point is absolute blindness to color in the primitive man," and he urges that the sense of color has been gradually developed, "until it has now become a familiar and unquestioned part of our inheritance." He adds: "Perhaps one of the most significant relics of the older state of things is to be found in the preference (known to the manufacturing world) of the uncivilized nations for strong and, what is called in the spontaneous poetry of trading phrases, loud color." †

Dr. Magnus holds the view that the color sense in man has undergone a great improvement within the last 2,000 years, and Prof. Haeckel supports this speculation, but it is opposed by Romanes, who has favored me with some observations on the subject, in view of this lecture; and it seems to me strange, if savage nations are really deficient in the sense of color, that the use of such colors as they can get in metals and fabrics, blended, for instance, in a war club or a pipe stem, should be so thoroughly "understood" and so discriminatingly employed as we sometimes find them to be. It may further be observed that primitive man may even have derived from his more remote ancestry some power of being influenced by color, and we are told that the attraction which gorgeous coloring in flowers has for birds and insects, and which color generally possesses for our nearer ancestors, has been of great importance in the origin of species and in the maintenance of organic life.

No doubt, in ancient times, there was much confusion between mere brightness and color, such as is evident in the beautiful sentence in which St. Augustine ‡ says: "For this *queen of colors, the light*, bathing all which we behold, wherever I am through the day, gliding by me in varied forms, soothes me when engaged on other things and not observing her." If, however, it were proved that the power of distinguishing the color of metals was not widely diffused among the Egyptians, Hebrews, and Greeks, it is at least certain that there were individuals of these nations to whom, in very early times, the color of metals was all-important; and although they may have confused different precious stones under generic names, they certainly appreciated their various colors, and knew, moreover, that by fusing sand with the addition of a small quantity of certain minerals, they could produce artificial gems of varied tints.

My object in leading you so far back—in discussing what appears to be a very matter-of-fact subject—is to point to the close connection between the early recognition and appreciation of color in metals or minerals and the foundation of the science of chemistry.

In early scientific history the seven metals known to the ancients were supposed to be specially connected with the seven principal planets whose names they originally bore, and whose colors were reflected in the metals. Thus gold resembled the sun, silver the moon, while copper borrowed its red tint from the ruddy planet Mars. The belief in the intimate relation between colors and metals, the occult nature of which they shared, was very persistent, and we find a seventeenth century writer, Sir John Pettus, saying § that "painters" derive "their best and most proper colors from metals whereof seven are accounted the chief, produced from the seven chief metals, which are influenced by the seven planets."

A survival of this feeling is suggested by a modern writer, Leslie, who supposed that "when Newton attempted to reckon up the rays of light decomposed by the prism, and ventured to assign to them the famous number seven, he was apparently influenced by some lurking disposition toward mysticism." ‖

It would be impossible for me to overrate the importance of the color of metals in relation to scientific history, for the attempt to produce a metal with the color and properties of gold involved the most intense devotion to arduous research, sustained by feverish hope, attended by self-deception and elaborate fraud, such as hardly any other object of human desire has developed. It led to despair, to madness, and to death. But finally, through all, alchemy prepared the way for the birth of chemistry, and for the true advancement of science.

In early times, as now, gold was an extremely desirable form of portable property, and its color was, perhaps, held to be the most distinctive and remarkable fact about it. I may incidentally observe that the dominant idea of color in connection with the metallic currency survives in the familiar phrase, "I should like to see the *color* of his money," which curiously expresses a desire, tempered by doubt as to its fulfillment. On looking back, we find that, at least from the third to the seventeenth century, the color of gold haunted the early experimenters, and induced them to make the strangest sacrifices, even of life itself, in the attempt to imitate, and even actually to produce, the precious

* A lecture delivered on Sept. 3, 1886, by Prof. W. Chandler Roberts-Austen, F.R.S., to the Operative Classes in the Town Hall of Birmingham, in connection with the meeting of the British Association.—*Nature.*

* "Modern Painters," vol. i., part 2, p. 201, 1851.

† *Nineteenth Century*, p. 367, 1877.

‡ "Confessions of St. Augustine." Edition edited by E. B. Pusey, D.D. (p. 211).

§ "Fleta Minor," 1686, Appendix, "Essay on Metallic Words—Color."

‖ "Treatises on Various Subjects of Natural and Chemical Philosophy."

metal. Let us see what kind of facts were known within the period I have indicated. In barbaric times, hammered pieces of gold, or gold beaten into thin sheets and plates, were used with colored stones and coral for personal adornment. The next step was to make gold go further by gilding base metals with it, and, in order to do this, the color was for the moment sacrificed by combining the gold with quicksilver. This was done at least in the time of Vitruvius, B.C. 80, heat being used to drive away, as vapor, the quicksilver which had been united to the gold, leaving a thin film of precious metal on the surface to be gilded. But this was possibly not the first method of gilding, for we now know, from a papyrus of about the third century * of our era, that lead was used for this purpose. Gold, when fused with lead, entirely loses its golden color, and yet, by the application of heat in air, the lead may be made to flow away as a fusible oxide, leaving the precious metal on the metallic object to be gilt, the base metal being as it were transmuted, superficially at least, into gold. The point I want to insist upon is that the metallic color of the gold vanished during the process as carried on by the craftsman, only to reappear at the end of the operation; and I am satisfied that it was from such simple technical work as this that the early chemists were led to think that the actual production of gold—the transformation of base metals into gold—was possible. The more observant of them, from Geber, the great Arabian chemist of the seventh century, to our own countryman, Roger Bacon, in the thirteenth, saw how minute a quantity of certain substances would destroy the red color of copper or the yellow color of gold. A trace of arsenic will cause the red color of copper to disappear; therefore, the alchemists very generally argued, some small quantity of the right agent, if only they could find it, will turn a base metal to the color of gold. Look, they said, how small a quantity of quicksilver will change the appearance of metallic tin. Here is a bar of tin two feet long and one inch thick, which it would be most difficult to break, though it will readily bend double. If only I rub a little quicksilver on its surface a remarkable effect will be produced, the fluid metal will penetrate the solid one,† and in a few seconds the bar will, as you see, break readily, the fractured surface being white, like silver. It was by such facts as this that men were led to believe that the white metal, silver, could be made.

Successive workers at different periods held divergent views as to the efficacy of the transmuting agent. Roger Bacon, in the thirteenth century, held that one part of the precious substance would suffice to turn a million parts of base metal into gold. Basil Valentine, in the fourteenth century, would have been content with the transmutation of seventy parts of base metal by one part of the agent. While, coming to the end of the eighteenth century, Dr. J. Price, F.R.S., of Guildford, only claimed that the substance he possessed would transmute from thirty to sixty parts of base metal.‡

It is a curious fact that no one seems to have actually prepared the transmuting agent for himself, but to have received it in a mysterious way from "a stranger;" but I must not dwell on this. I will merely point out how persistent was the view as to the singular efficacy of the transmuting agent, and I will content myself with a reference to Robert Boyle, our great countryman, an accurate chemist of the seventeenth century, who did more than any one else to refute the errors of alchemy. He nevertheless characteristically records§ the following experiment, in which, instead of ennobling a base metal, he apparently degraded gold to a base one. He first purified a small quantity of gold, about "two drachms," with great care, and, he states, "I put to it a small quantity of powder communicated to me by a stranger"—it is singular that even he should have received the transmuting agent in the usual way—"and," he adds, "continuing the metal a quarter of an hour on the fire, that the powder might diffuse itself through it, . . . the metal when cold appeared to be a lump of *dirty color*; . . . 'twas brittle, and, being worked with a hammer, it flew into several pieces. From hence," he adds, "it appears that an operation almost as strange as that called 'projection'" (or transmutation) "may safely be admitted, since this experiment shows that gold, . . . the least mutable of metals, may in a short time be exceedingly changed . . . by so small a portion of matter that the powder transmuted a thousand times its weight of gold." He elsewhere observes of a similar experiment, "transmutation is nevertheless real for not being gainful, and it is no small matter to remove the bounds which nature seems very industriously to have set to the alterations of bodies."‖ The change in the color of the gold was remarkable, but Boyle had only produced one of the series of alloys most dreaded by every jeweler—"brittle gold"—for the way in which an alloy of gold and copper is affected by a small quantity of impurity presents one of the most serious difficulties in working gold. It has been known since the seventh century that minute quantities of certain metals render gold brittle, and it may be well to demonstrate the fact.

Here are two hundred sovereigns; I will melt them and will add in the form of a tiny shot a minute portion of lead amounting to only the 2,000th part of the mass, first, however, pouring a little of the gold into a small ingot, which we can bend and flatten, thus proving to you that it is perfectly soft, ductile, and workable. The rest of the mass we will pour into a bar, and now that it is sufficiently cold to handle, you see that I am able to break it with my fingers, or at least with a light tap of a hammer. The *color* of the gold is quite altered, and has become orange brown, and experiments have shown that the tenacity of the metal, that is, the resistance of the gold to being pulled asunder, has been reduced from 18 tons per square inch to only 5 tons.

* "Les Origines de l'Alchimie," par M. Berthelot, 1885, pp. 82, 89. It is interesting to compare the account of this method of gilding by lead with the expression used by Homer, who says: "As when gold is *fused* around the silver by an experienced man."—"Odyssey," vi., 232-35, quoted by Schliemann, "Ilios," p. 258, in relation to a gilded knife of copper which he permitted me to analyze in 1878.

† Homberg, *Mem. de l'Acad. Royale des Sciences*, 1713 (vol. published 1739), p. 308.

‡ "An Account of Some Experiments on Mercury, Silver, and Gold made at Guildford, in the Laboratory of James Price, M.D., F.R.S.," Oxford, 1782.

§ "The Philosophical Works of the Hon. Robert Boyle" (Shaw's second edition), 1738, vol. i., p. 78.

‖ *Ibid.*, p. 302.

These essential changes in the property of the metal have been produced by the addition of a minute quantity of lead. I have cited these facts mainly to show that the changes produced in the color and properties of metals by small variations of composition were such as to lead the alchemists on in their belief that it was possible to change lead or tin into gold, and the hope in which they worked enabled them to gather facts out of which chemical science was gradually constructed. We shall see presently that changes in the color of metals and alloys, produced by the addition of small quantities of foreign matter, are of great importance in the application of metals to artistic purposes, but we must first try to examine more closely some of the prominent facts connected with the color of metals, that is, the effect metals have on light, so as to produce the effect of color in our eyes. We are apt to think of gold as being essentially and distinctively golden yellow; it may, however, possess a wide range of colors without in any way losing the condition of absolute metallic purity, its relations to light depending entirely on the nature of its surface, and especially on whether the metal is in mass or in a more or less fine state of division. Interesting as gold is to us in mass (and I may incidentally mention that during my official connection with the Mint I have been responsible for the quality of 462 tons of it), it is perhaps still more interesting to us when beaten so fine that a single grain, of the value of 2*d*., would cover a space of 48 square inches, or when it is so finely divided that the dimensions of a single particle may closely approximate to those of the ultimate atom.

This aspect of the question was investigated by Faraday, and the experimental part of the subject remains practically unadded to since his time. It is well known that a leaf of gold when seen by transmitted light is either green or blue, according to its thickness. Here is such a leaf of green gold, as seen when light is actually sent through it (Fig. 1), so as to project a green

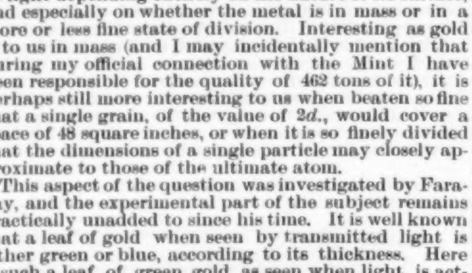


Fig. 1.

disk on the screen. A portion of the light will be *reflected* from its surface, and this reflected ray may be caught in a mirror and thrown on the screen so that you have shown side by side the green disk of transmitted light and the golden one of reflected light from the same leaf of gold.

Gold may readily be converted into a soluble chloride which produces a beautiful golden solution. If such a solution contains very little gold, not more than 2 grains in a gallon, and if certain chemical methods be adopted to precipitate the gold, that is, to throw it out of solution in a *solid*, though in a very fine state of division, the metal may exhibit a wide range of tint, from ruby to black.

[A few drops of phosphorus dissolved in bisulphide of carbon had been added to about a gallon of a very dilute solution of chloride of gold contained in a tall glass cylinder as shown in the sketch (Fig. 2). The

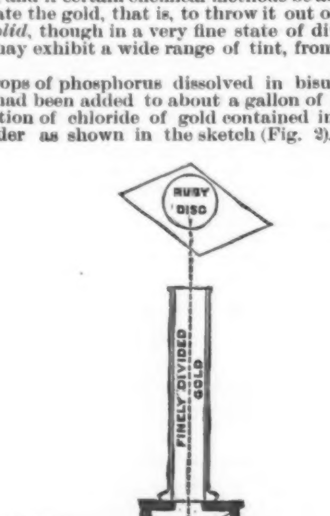


Fig. 2.

beam from an electric light, thrown through the vessel, revealed in the lower part the presence of finely divided metal of the natural golden color, while the more finely divided gold in suspension imparted a brilliant ruby color to the liquid, and a glowing ruby disk was projected on a white screen.]

When gold is in the "ruby" state, it is so finely divided that each particle probably approximates to the dimensions of the gold atom.

[The solar spectrum was then thrown upon the screen and the audience was invited to compare it with a diagram which, while closely resembling the solar spectrum, really represented the way in which pure metallic gold, prepared by various methods, is capable of behaving in relation to light so as to produce the sensation of a wide range of colors.]

It would be easy to show that light is similarly affected by other metals; but I have selected gold for the purpose of illustration because it is easy to maintain it in a state of purity, however finely divided it may be. We must therefore modify any views we may have formed as to a metal having exclusively a special color of its own, because it will be evident that a particular color is only due to a definite state of arrangement of its particles. The intimate relation between the state of the surface of a metal and its color is well shown by the beautiful buttons devised by Sir John Barton. He proved that if very fine lines be drawn close together, so that about 2,000 would be ruled in the space of an inch, a beautiful iridescent effect is produced, the tints being quite independent of the metal itself, due to an optical effect of the lines.

[The image of such a button was then thrown upon the screen.]

Let us now examine some effects of uniting metals by fusing them together into what are called alloys; and, second, the direct influence of a minute quantity of one metal in changing the mass of another in which it is hidden, and causing it to behave in a different way in relation to light, and consequently to possess a color different from that which is natural to it; or the added metal may so change the chemical nature of the metallic mass that varied effects of color may be produced by the chemical combinations which result from the action of certain "pickling" solutions. This portion of the subject is so large that I can only hope to set before you certain prominent facts.*

First, with reference to the color produced by the union of metals. Here is a mass of red copper, and here one of gray antimony; the union of the two by fusion produces a beautiful violet alloy when the proportions are so arranged that there is 51 per cent. of copper and 49 per cent. of antimony in the mixture. This alloy was well known to the early chemists, but unfortunately it is brittle and difficult to work, so that its beautiful color can hardly be utilized in art. The addition of a small quantity of tin to copper hardens it, and converts it, from a physical and mechanical point of view, into a different metal. The addition of zinc and a certain amount of lead to tin and copper confers upon the metal copper the property of receiving, when exposed to the atmosphere, varying shades of deep velvety brown, characteristic of the bronze which has from remote antiquity been used for artistic purposes. But by far the most interesting copper alloys, from the point of view of color, are those produced by its union with zinc, namely, brass. Their preparation demands much care in the selection of the materials, and I might have borrowed from the manufacture of brass instance after instance of the influence of traces of impurity in affecting the properties of the alloy, but it is unnecessary to dwell upon this alloy in Birmingham, for in all that relates to the mechanical manipulation of the alloys of copper with tin and with zinc you are masters. I have many inducements in this place to speak about this beautiful alloy. I am proud to be a namesake of the craftsman William Austen, who, in 1460, made that magnificent monument in brass which covers the remains and commemorates the greatness of Richard Beauchamp, Earl of Warwick, and I am glad to remember that Queen Elizabeth granted the first patent for the manufacture of brass in England to William Humfrey, Assay Master of the Mint, a predecessor in the office it is my privilege to hold.

I want, however, to direct your attention to-night to some alloys of copper with which you are probably less familiar than with brass. In this direction Japanese art affords a richer source of information than any other. Of the very varied series of alloys the Japanese employ for art metal work, the following may be considered to be the most important and typical:

Shaku-do.

I.		II.	
Copper	94·50	Copper	95·77
Silver	1·55	Silver	0·08
Gold	3·73	Gold	4·16
Lead	0·11		
Iron and arsenic	traces		100·01
	99·89		

The first is called 'shaku-do;" it contains, as you will observe from Analyses I. and II.,† in addition to about 95 per cent. of copper, as much as 4 per cent. of gold. It has been used for very large works. Colossal statues are made of it; one cast at Nara in the seventh century being specially remarkable. The quantity of gold is, however, very variable; specimens I have analyzed contained only 1·5 per cent. of the precious metal.

Shibu-ichi.

III.		IV.	
Copper	67·31	Copper	51·10
Silver	32·07	Silver	48·93
Gold	traces	Gold	0·12
Iron	0·52		
			100·15
	99·90		

The next alloy to which I would direct your attention is called "shibu-ichi." There are numerous varieties of it, but in both these alloys, shaku-do and shibu-ichi, the point of interest is that the precious metals are, as it were, sacrificed in order to produce definite results; gold and silver, when used pure, being employed very sparingly to heighten the general effect. In the case of the shaku-do, we shall see presently the gold appears to enable the metal to receive a beautiful rich purple coat or *patina*, as it is called, when treated with certain pickling solutions; while shibu-ichi possesses a peculiar silver gray tint of its own, which, under ordinary atmospheric influences, becomes very beautiful, and to which the Japanese artists are very partial. These are the principal alloys, but there are several varieties of them, as well as combinations of shaku-do and shibu-ichi in various proportions, as, for instance, in the case of kiu-shibu-ichi, the composition of which would correspond to one part of shaku-do rich in gold, and two parts of shibu-ichi rich in silver. Interesting effects are produced by pouring two alloys of different tints together just at the solidifying point of the less fusible of the two, so that the alloys unite but do not blend, and a mottled surface is the result. These alloys are introduced into almost every good piece of metal work.

Now as to the action of pickling solutions. Many of you will be familar with the mysteries of the treatment of brass by "dipping" and "dead dipping," so as to produce certain definite surfaces, but the Japanese art metal workers are far ahead of their European brothers in the use of such solutions.

The South Kensington Museum contains a very valuable series of fifty-seven oblong plates, some plain and

* A list of books and papers dealing with the colors of metals and alloys, and with the production of colored patina, is given by Prof. Ledebur in his work, "Die Metallverarbeitung," p. 285, 1882, published in Bolley's "Technologie."

†Analyses Nos. I. and III. are by Mr. Gowland, of the Imperial Japanese Mint at Osaka; Nos. II. and IV. by Prof. Kalischer, *Dingl. Polyt. Journ.*, ccxv., 96.

others richly ornamented, which were specially prepared as samples of the various metals and alloys used by the Japanese. The Geological Museum in Jermyn Street has a smaller, but very instructive, series of twenty-four plates presented by an eminent metallurgist, the late M. Hochstatter-Godfrey. From descriptions accompanying the latter, and from information I have gathered from certain Japanese artificers now in London, it would appear that there are three solutions generally in use. They are made up respectively in the following proportions, and are used boiling:

	I.	II.	III.
Verdigris....	438 grains.	87 grains.	220 grains.
Sulphate of copper.....	292 "	437 "	540 "
Niter........	—	87 "	—
Common salt	—	146 "	—
Sulphur....	—	233 "	—
Water.......	1 gallon.	—	1 gallon.
Vinegar.....	—	1 gallon.	5 fl. dr.

That most widely employed is No. I. When boiled in No. III. solution, pure copper will turn a brownish red; and shaku-do, which, you will remember, contains a little gold, becomes purple; and now you will be able to appreciate the effect of small quantities of metallic impurity as affecting the color resulting from the action of the pickle. Copper containing a small quantity of antimony gives a shade very different from that resulting from the pickling of pure copper. But the copper produced in Japan is the result of smelting complex ores, and the methods of purification are not so perfectly understood as in the West. The result is that the so-called "antimony" of the Japanese art metal workers, which is present in the variety of copper called "kuromi," is really a complex mixture containing tin, cobalt, and many other metals, so that a metal worker has an infinite series of materials at command with which to secure any particular shade; and these are used with much judgment, although the scientific reasons for the adoption of any particular sample may be hidden from him. It is strictly accurate to say that each particular shade of color is the result of minute quantities of metallic impurity, and these specimens and diagrams will, I trust, make this clear, and will prove that the Japanese arrange true pictures in colored metals and alloys.

[This portion of the subject was illustrated with much care by colored diagrams representing specimens of Japanese art metal work, by photographs projected on the screen, as well as by the reflected images of small ornaments made of the alloys which had been specially referred to. There was also a trophy of leaves of copper of varying degrees of purity, colored brilliantly by one or other of the "pickles" above described.]

There is one other art material to the production of which I hope art workmen in Birmingham will soon direct their attention, as its applications are endless. It is called in Japanese "mokume," which signifies "wood grain." It is now very rare even in Japan, but formerly the best specimens appear to have been made in Nagoya by retainers of the Daimio of Owari. I have only seen six examples, and only possess a single specimen of native work, and have therefore had to prepare a few illustrations for you in soldered layers of gold, silver, shibu-ichi, shaku-do, and kuromi.

This diagram (Fig. 3) shows the method of manufacture.

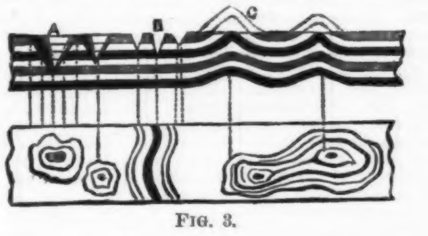


FIG. 3.

Take thin sheets of almost any of the alloys I have mentioned, and solder* them together layer upon layer, care being taken that the metals which will present diversity of color come together. Then drill conical holes of varying depth, A, in the mass, or devices in trench-like cuts of V section, B, and hammer the mass until the holes disappear. The holes will thus be replaced by banded circles and the trenches by banded lines. A Japanese artificer taught me to produce similar effects by taking the soldered layers of the alloy, and by the aid of blunted tools making depressions on the back of the mass so as to produce prominences on the front, C. These prominences are filed down until the sheet is again flat; the banded alloys will then appear on the surface in complicated sections, and a very remarkable effect is produced, especially when the colors of the alloys are developed by suitable "pickles." In this way any device may be produced. In principle the method is the same as that which produces the *damascening* of a sword blade or gun barrel, and depends on the fact that under certain conditions metals behave like viscous solids, and as truly "*flow*" as pitch or honey does, only in the case of mokume the art workman has a wide range of tinted metals at command.

Throughout Japanese art metal work, in which I hope you will take increasing interest, there is one principle of extreme simplicity and absolute fidelity to nature. The brilliant metals, gold and silver, are used most sparingly, only for enrichment, and to heighten the general effect. These precious metals are never allowed to assert themselves unduly, and are only employed where their presence will serve some definite end in relation to the design as a whole. A Japanese proverb asserts that "He who works in gold puts his brains into the melting pot," meaning, I suppose, that this metal, so precious from an artistic point of view, demands for its successful application the utmost effort of the workman, and suggesting that gold should not be employed in massive forms such as would result from melting and casting, but should be daintily handled, beaten on to the work, or embedded with the hammer.

Bear in mind that in Birmingham, when a really fine work is produced in silver, the surface is often made gray by chemical means, "oxidized," as it is termed, and this subordination of the brilliancy of silver to artistic effect is well understood by the celebrated American firm, Messrs. Tiffany, of New York, who are doing so much to catch the spirit of Japanese art metal work. All I ask you to do is to carry this still further—to cover base metals with these glowing colored oxides, and thus to add to the permanence of art work, by producing surfaces which will resist the unfavorable atmospheric influences of our cities.

Hitherto we have considered the union of metals by fusion; but fire is not the only agent which can be employed for this purpose. Two or more metals may be deposited side by side by the aid of the electric battery. Birmingham was, as you well know, the early home of electro-metallurgy, an industry to the development of which the great firm of Elkington has so materially contributed. I have no statistics as to the amount of precious metals annually employed for electro-deposition in Birmingham, but it is known that a single works in Paris, belonging to M. Christofle, deposits annually six tons of silver, and it has been estimated that the layer of silver of the thickness actually deposited on various articles would, if spread out continuously, cover an area of 140 acres.* I will not, however, dwell upon the deposition of gold and silver in their normal colors. I would remind you that copper and zinc may be deposited by electrolysis so as to form brass, and that all the beautiful bronzes and alloys of the Japanese can be obtained by galvanic agency; and further, by suitable admixtures of gold, silver, and copper, red gold, rose colored gold, or green gold may be deposited, so that the electro-metallurgist has at his command the varied palette of the decorative artist.

[The images of beautiful deposits of colored gold, specially prepared by Messrs. Elkington, were then projected on the screen.]

I ought to allude to what has been called the moral aspect of color; and although I cannot follow Goethe† in his attributes of color, which seem to me to be fantastic and overstrained, I quite recognize the poetic sympathy of Shakespeare in making Bassanio select the casket of lead, which contained the warrant for his earthly happiness, because "its paleness moved him more than eloquence." I ask you to remember Ruskin's words, that "all men completely organized and justly tempered enjoy color; it is meant for the perpetual comfort and delight of the human heart; it is richly bestowed on the highest works of creation, and the eminent sign and seal of perfection in them, being associated with life in the human body, with light in the sky, with purity and hardness in the earth; death, night, and pollution of all kinds being colorless."

I must briefly turn to the concluding part of our subject. It has long been known that thin films of certain metals and certain metallic oxides act on light in the same way as thin films of other translucent substances. I have here such thin films of oxide of lead, which, many years ago, Nobili, Becquerel, and Gassiot taught us to deposit, and such films have since been used in decorative metal work.

[Beautiful examples of such films were projected on the screen.]

I wish I had time to point to the great interest and importance of films of colored oxide of iron in the tempering of steel, for it is well known that, apart from the scientific interest of the subject, the shades, from straw colored to blue, which pass over the surface of hardened steel when it is heated in air afford precious indications as to the degree of temper the metal has attained, and in no industry is this better shown than in the manufacture of steel pens. I must pass this over, and turn to one other instance of the formation of colored films on metals. Here is an ordinary plumber's ladle filled with lead, which will soon be molten when it is placed over this flame. The air will play freely on the surface of the melted lead, and, as a certain temperature is reached, very beautiful films will pass over the surface of the metal. If the lead contains very minute quantities of cadmium or of antimony, the effect will be greatly heightened. If the light from the electric lamp be allowed to fall on the surface of the bath of lead, it will be easy to throw the image of the metallic surface on the screen, and you will see how beautiful the films are and how rapidly they succeed each other when the metal is skimmed. What, then, is the special significance of the experiment from our point of view? It represents in a singularly refined way the one experiment which stands out prominently in the whole history of chemistry; for the formation of a colored scum on lead when heated in air has been appealed to, more than any other fact, in support of particular sets of views from the time of Geber, in the seventh century, to that of Lavoisier, in the eighteenth. It was the increase in weight of the lead when heated in air that so profoundly astonished the early chemists; and, finally, the formation of a colored oxide by heating lead in air was the important step which led on your great townsman, Priestley,‡ to the discovery of oxygen; and, as the fact of his residence among you will never be forgotten, Birmingham may claim to have been connected, through him, with one of the most splendid contributions ever offered to chemical science.

THE FADING OF WATER COLORS.

To the Editor of the Chemical News:

In the course of some experiments on the action of sunlight on water color paints, I found that some mineral colors which did not contain "lead or mercury" were far from permanent when exposed to daylight in the presence of moisture.

The paints experimented on (Winsor & Newton's moist water colors) were brushed thickly over Whatman's best drawing paper, and exposed in an atmosphere of dry and of damp air to the action of daylight, one-half of each strip being protected from the action of the light.

Cadmium yellow in damp air was entirely bleached on the parts exposed to light in two weeks, but remained absolutely unaltered in dry air.

Prussian blue in damp air was entirely bleached after four weeks' exposure, remaining permanent in dry air.

Yellow ocher faded slightly in the presence of moisture after four weeks' exposure, no change being observed in dry air.

In the case of the organic colors experimented on—viz., crimson-lake, rose-madder, gamboge, and indigo—the colors were discharged as rapidly in dry as in damp air.

That the fading of cadmium yellow (cadmium sulphide) was caused by oxidation of the yellow sulphide to the white sulphate was shown by treating the bleached paper with water slightly acidified with hydrochloric acid. On adding sulphureted hydrogen water to one portion of this solution, the yellow sulphide of cadmium was precipitated, while the other portion gave a white precipitate of barium sulphate on addition of barium chloride.

These experiments have been carried on within the last two months, during which time the light has been very feeble. ARTHUR RICHARDSON.

University College, Bristol, December 1, 1886.

INFLUENCE OF CHANGE.

AT a recent meeting of the Physical Society, under the chairmanship of Professor McLeod, a paper was read on "The Influence of Change of Condition from the Liquid to the Solid State on Vapor Pressure," by Professor W. Ramsay and Dr. Sydney Young. The investigation bore relation to the researches by Fischer and others on the vapor pressures of ice and water at the same temperatures, also of solid and liquid benzine. The authors argued that Fischer's results, if properly calculated, show that the two curves of benzine do actually meet at the melting point. They had great difficulty in getting pure benzine for the experiments—that sold as such being far from pure.

The best commercial sample had to be frozen several times, shaken up with sulphuric acid, and otherwise treated. The best sample thus obtained had a melting point of 5·58. The apparatus used in the experiments consisted of a bulb, A (Fig. 1), in a vessel, B, filled with

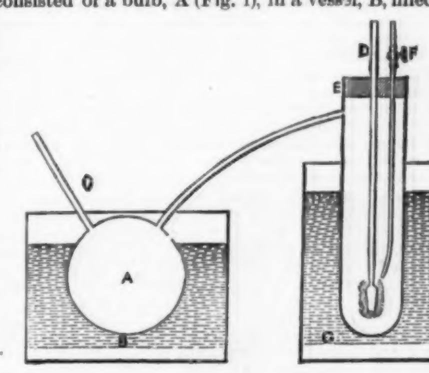
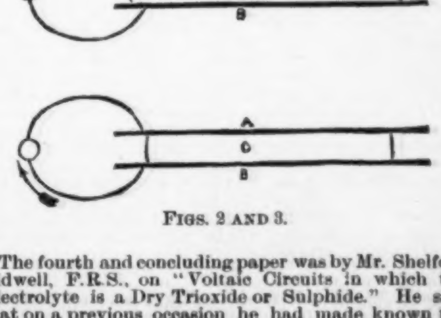


FIG. 1.

a freezing mixture; the tube, C, was connected with a gauge; the thermometer stem, D, passed through the cork, E, into the tube below, and its bulb was surrounded with cotton wool; the benzine was admitted through the stopcock, F, to a descending tube, whereby the cotton wool could be moistened by it at will; the vessel, G, was filled with warm water to promote evaporation. In some cases the adoption of Biot's formula caused the results of the authors to agree more closely with those of Fischer, and their general conclusion was that they were in a position now to say that both by the statical and dynamical methods it had been proved that the vapor pressure of a solid is always less than that of a liquid, and that the two curves always meet at the same temperature at the same melting point.

The next paper was by the same authors, and upon "The Nature of Liquids, as shown by a Study of the Thermal Properties of Stable and Dissociable Bodies." They called attention to the one view, that there is no great difference between the molecules of a liquid and of a gas beyond the molecules of the liquid being closer together, and to the chemical view, that in a liquid the molecules are in a radically different condition to that of their gaseous state. Experiments were tried with stable compounds, such as ether and alcohol, and less stable compounds, like acetic acid and nitric peroxide. The resulting argument was that there is no tendency in stable vapors to combine to form chemical compounds, and that the vapor pressure of acetic acid is not absolute, but an average, such as that which would be due to a mixture, in which case there may be a tendency to chemical combination of the molecules.

The third paper was by Mr. James Walker, on "Cauchy's Theory of Reflection and Refraction."



FIGS. 2 AND 3.

The fourth and concluding paper was by Mr. Shelford Bidwell, F.R.S., on "Voltaic Circuits in which the Electrolyte is a Dry Trioxide or Sulphide." He said that on a previous occasion he had made known the following experiment: A (Fig. 2) was a plate of copper, B a plate of silver, C a layer of dry sulphide of copper, and D a layer of dry sulphide of silver, all pressed to-

* The following solder was found to answer well:

Silver......	55·5
Zinc......	26·0
Copper......	18·5
	100·0

* H. Bouilhet, *Ann. de Chim. et de Phys.*, t. xxiv., p. 549, 1881.

† Farbenlehre.

‡ He pointed out that the experiment with minium confirmed his view that the mercury calcined in air derived oxygen *from* the air.

gether by means of a vise. This arrangement sent a current through the galvanometer in the direction denoted by the arrow. In a more recent experiment, he had tried the influence of peroxide of lead, because its conductivity is good, and it easily parts with its oxygen. In this experiment, A (Fig. 3) is a slice of sodium, B a plate of lead, and C the peroxide of lead between them. When connected with the galvanometer, there is a strong current from the sodium to the lead.

It might be argued that the electrolyte was watery, but he had dried it as much as possible by heating, and afterward by keeping it over sulphuric acid for a long time. Nevertheless, it always gave a strong current when the circuit was formed. In the sulphide experiment there was no possibility of its being due to moisture, because the current was always from the copper to the galvanometer. In another experiment with a plate of zinc, a plate of platinum, and moistened carbonate of lime, a deflection was given upon a Thomson's reflecting galvanometer; but no deflection was obtained when dry peroxide of lead was substituted for the damp chalk.

SOAP BUBBLES.*

THE curious and beautiful phenomena displayed by bubbles have for many centuries attracted attention. In the Museum of the Louvre in Paris is an Etruscan vase on which is depicted a group of children blowing bubbles. We thus learn, not only that that popular sport is of considerable antiquity, but that an early potter, like a well-known Royal Academician of to-day, found in it a fitting theme for artistic treatment. It would have been strange if such well-known natural phenomena had been ignored by those whose special desire it is to attempt to interpret Nature. Scientific men have long and carefully studied soap bubbles, and much has been learned concerning them. They present, however, many problems which, though of great interest, are as yet unsolved, and I am only echoing a remark once made to me by the late lamented Professor Clerk Maxwell when I say that he who can first adequately explain the constitution and behavior of a soap bubble will have made a great advance in the theory of the molecular constitution of liquids. I have no such ambitious aim before me; but I make these preliminary remarks to impress upon you that, trivial as the subject of my lecture may seem, it is, nevertheless, of no inconsiderable scientific importance. Without further introduction, I shall ask your attention while I discuss what seems to me one of the most interesting, as it has certainly been one of the most neglected, of the phenomena which a soap bubble displays. The explanation of the colors of these films is one of the triumphs of the theory of light. It is unnecessary to dwell upon it, as it may now be considered as one of the commonplaces of science. I am, however, anxious that the fact should be clearly before you, that the colors of soap bubbles not only enable us to measure their thickness, but, within certain limits, enable us to measure it with very great accuracy. The thickness even of a thick film is so small that it is convenient to employ a very small unit of length in describing it. I shall use the micromillimeter, that is, the millionth of a millimeter, or the twenty-five millionth part of an inch. No colors are displayed by thick films; but they begin to appear at a thickness which, if the film be viewed obliquely, may be fixed, in round numbers, as 2000 micromillimeters. At first, faint reds and greens succeed each other, and each pair—a red and the green—which follows it are called an order of colors. As the film becomes thinner, the colors become more numerous and brighter, till, in the orders which indicate considerable tenuity, orange, yellow, blue, and violet may also be distinguished. If the film last long enough to reach the last stages of thinness, it displays the colors of the first order. They are red, orange, yellow, white, gray, and black. When once the black is reached, no further change is observed. If the film becomes thinner, no evidence is afforded by the color, which is, according to Newton, black for all thicknesses less than 36 micromillimeters. It is difficult for two observers to agree as to the precise thickness at which any particular color occurs, as it is practically impossible for one person to describe the precise tint he has observed. I find, however, that Professor Quirsche and I agree as to the points at which each order begins (*i. e.*, the thicknesses at which the blues or purples of one order pass into the reds of the next) to about 3 per cent. Two estimates of the thickness of a film made by myself agree, in eighty cases out of every hundred, to within 2 per cent., so that neither differs from the mean by more than 1 per cent. It is not, then, too much to say, that over the greater part of the range of thicknesses for which colors are visible, they enable us to measure the thickness of a film to 1 per cent. The measurements are less accurate when the film is thin enough to show colors of the first order; and when it displays the black, no deduction can be drawn from its color, except that the thickness is less than 36 micromillimeters. In this case, then, as in so many others, information fails us just when it would be most interesting, for it is from the study of very thin films that we may hope to learn most. The molecules of which a liquid is composed are bound together by forces which are in play between them. The attractive force between two molecules decreases very rapidly as the distance between them increases, and if that distance exceeds a certain very small limit, called the radius of molecular action, the force is so slight that it may be disregarded altogether. If, then, we conceive a molecule in the interior of a liquid as placed at the center of a small sphere, the radius of which is equal to the radius of molecular action, we may regard it as acted on only by other molecules which lie within the sphere. These will be distributed symmetrically around it, and it will thus be attracted equally in all directions. A molecule in the surface is under different conditions. It has neighbors on one side only, and thus the forces exerted upon it are not the same as if it were deeply immersed. As a result of this, the molecules in the surface, and in the interior, will be differently arranged or packed together, and as the physical properties of a body depend not only on the chemical constitution of its molecules, but also on their arrangement among themselves, we should *a priori* expect that the properties of the surface and of the interior of a liquid would be in some respects different. That this is so is well known, and we must, therefore, regard a thick soap film as made up of three parts—an interior, throughout which the physical properties are at all points the same, and two very thin surface layers, in which they are different. We may regard the thinning of the film as a draining away of the interior liquid, and if it becomes sufficiently thin, the two surface layers will meet and intermingle. If this state of things could be attained, the film would almost certainly display novel phenomena, which would throw light on the nature of the molecular forces; and the first question which suggests itself to the student of thin films is whether a black film affords any indication that the extreme tenuity necessary to produce such results has been reached. The phenomenon to which I wish to draw your attention is, from this point of view, very significant. In general, the colors of the different parts of a soap film fade imperceptibly, the one into the other, so that it is difficult to fix on any boundary which shall separate them. This gradual change in the tints indicates that the thickness also varies gradually and continuously from point to point. At the edge of the black, however, there is always (except under very special conditions) a clear and definite boundary, which indicates a sudden change in thickness. The gray of the first order is always missing. Sometimes several tints, or even several orders of colors, are omitted between the black and the part of the film which is next to it. Sometimes, though only rarely, we have seen in contact the black and a part of the film so thick as to show no colors. In this case, if we suppose the black to have had its greatest possible thickness (and I shall presently show you it must have been much thinner), the thickness of the film must suddenly have increased from thirty-six to about 2000 micromillimeters. Such a phenomenon is never observed, except in the case of the black, and it is impossible for any one who has seen it, and noticed how regularly it occurs when the black appears, to doubt that it must be, in some way, caused by the extreme tenuity of the film. These and similar considerations led Professor Reinold and myself, some years ago, to undertake a closer study of the properties of soap films. We began by investigating their electrical resistance. For this purpose we had to select a liquid which forms films which will last a long time, and thin slowly. That which best answers these conditions is a mixture of soap, water, and glycerine. Such a liquid is, however, very subject to change, as it may, according to circumstances, either absorb the moisture of the air or lose some of the water it originally contained. It was, therefore, necessary that all the experiments should be made in closed glass box, in which the temperature and degree of dryness of the air were maintained constant. It was convenient to use cylindrical instead of spherical films, and whenever one of these broke another had to be formed without opening the box. The method of performing this operation will be understood from the accompanying Fig. 1. A platinum ring, F, which is

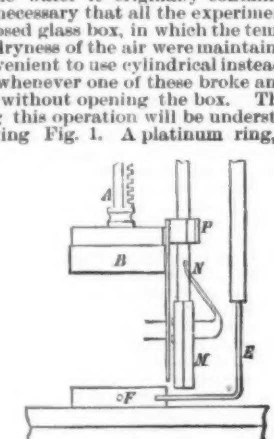


FIG. 1.

connected with the exterior by the rod, E, rests upon the bottom of the box; liquid is poured in in sufficient quantity to cover the botton, but not to reach the upper edge of F. By turning the wire, E, the ring, F, is moved aside, and another ring of the same diameter, B, is lowered by rack work, actuated by a pinion, which is also outside the box. If B is made to touch the liquid, and then withdrawn, a plane film forms across it. The ring, F, is replaced under B. Air is blown in through the tube, A, which carries the rack work. A bubble forms, which, when large enough, adheres to F, and if air be then sucked out, it assumes the form of a cylinder, uniting, and of the same diameter as, B and F. An electric current can then be passed from A through the liquid cylinder to F and E, the connections with A and E being made outside the box. The resistance of any part of the film is measured by introducing into it two gold wires (seen on the right of the figure), which are connected by the wires, N, with a quadrant electrometer. The difference of potential thus indicated is compared with that between two points separated by a known resistance in the same circuit.

These experiments enabled us to form an estimate of the thickness of a black film. Other things being equal, the resistance of a film might be expected to vary inversely as its thickness, and we proved that this law held good for films, the thickness of which was greater than 380 micromillimeters. If it might be extended to greater degrees of tenuity, we could calculate the thickness of a black film, by measuring its resistance, first, when it was thick enough to show a color from which its thickness could be inferred, and, secondly, when it had become black. If, in the latter case, the resistance was a hundred times greater than in the former, this indicated that the thickness was a hundred times less.

Two sets of experiments, made with an interval of several years, and with different liquids, gave closely accordant results. The means were 11·9 and 11·7 micromillimeters respectively. To check these results, we made other measurements by a totally independent method. If two plates of carefully worked glass are placed parallel to each other, as represented in Fig. 2, a beam of light, A B, falling upon the first at an angle of about 45°, will, at B, be divided into two rays, which, after pursuing different paths, will coincide again at E. One of these rays will be reflected at B, refracted into the second plate at C, reflected at its second surface at D, and refracted out at E, in the direction E H; the other will pursue the path, B, F, G, E, H. If, then, all the arrangements are perfectly symmetrical, the crests of two light waves will start simultaneously along the two paths from B, and will meet again at E.

If, owing to any cause, the two paths are not precisely similar, one wave may be a little retarded, and thus, instead of two crests meeting at E, the crest of one system of waves may arrive there at the same instant as the trough of the other. If this occurs, the two waves

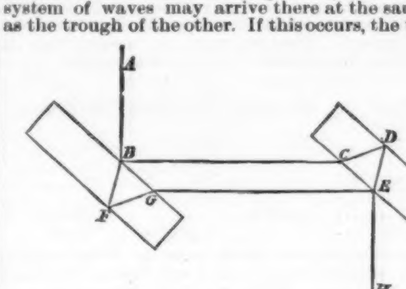


FIG. 2.

will, in accordance with the well-known principles of interference, destroy one another, and the point, E, will appear dark to an eye looking along H, E. This result is obtained if the two plates are not absolutely parallel, and alternate bands of light and darkness are seen, which correspond to the successive points at which the two systems of waves mutually re-enforce or destroy each other. Fig. 3 is a reproduction of a photograph of such a system of interference bands, taken for me by Mr. Haddon, of the Royal Naval College, Greenwich.

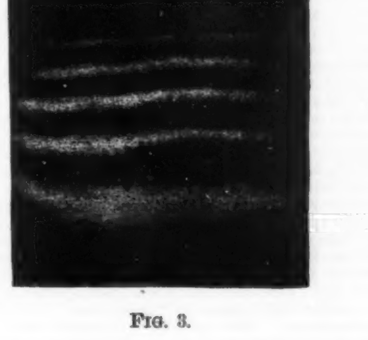


FIG. 3.

If, now, we introduce into the path of one of the interfering rays—say B, C—a thin plate of glass or a liquid film, the ray will be again retarded. Light travels more slowly in glass or water than in air, and the time which any given wave takes to travel along the path, B, C, D, E, will be longer than before. Thus the points at which interference occurs are altered, and the bands move. By appropriate measurements of the amount of this movement, we can, if the index of refraction of the plate interposed between B and C is known, calculate its thickness. A single black film is so thin that the shift of the interference band produced by it would have been immeasurably small. We, therefore, formed from forty to fifty parallel plane films, in a glass tube, and placed them in the path of one of the rays. When they had become black they were broken, and the movement of the bands caused by their removal from the path of the ray was measured.

Numerous precautions, which it would take too long to detail, were necessary to insure success. I may, however, shortly describe the method of breaking the films. The air within the tube which contained the liquid films was damp, and to maintain this in a constant state the ends of the tube were closed by two plates of glass. A very small movement of these would have produced an effect on the interference bands equal to or greater than that due to the breaking of the films. It was, therefore, important that the apparatus should not be in any way shaken or disturbed by the act of rupture. This end was attained by the method illustrated in Fig. 4. A part of the tube, containing a num-

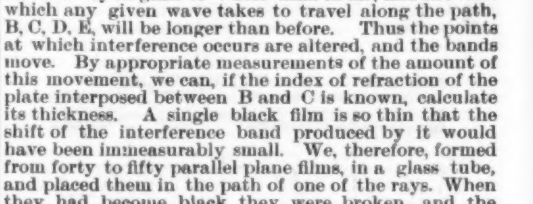


FIG. 4.

ber of films, is there represented. A needle had been inclosed with the films, and by means of a sufficiently strong electromagnet this could, without touching the apparatus, be raised into the position shown in the figure, and made to traverse the tube from end to end, breaking in its passage all the films it encountered. The mean of all the measurements made in this way agreed closely with the results previously obtained, being 11·4 instead of 11·8 micromillimeters.

In spite of the accord between these mean results, we are not prepared to assert that all black films are of the same thickness. On the contrary, the electrical experiments prove that they may vary between 7·2 and 14·5 micromillimeters. All observation indicates, however, that from the time of, or at all events from very soon after the time, of its formation, the whole of the black part of a film is of uniform thickness, and that this thickness remains unaltered, however long the film may last, and however large the black area may become

Summing up, therefore, three facts connected with the black part of a soap film require explanation, viz.: (1) The sudden change in thickness at its edge; (2) the

* A lecture delivered by Professor A. W. Rücker, F.R.S., before the British Association, Birmingham meeting, September, 1886.—*Industries.*

uniform thickness of the black film; (3) the wide variations in the thickness of the colored part of the film which appears to be in direct contact with the black. To explain these, we inquire what are the special properties of the surface of a liquid by which they might be produced, and there are two which require special consideration, viz., the viscosity and the surface tension.

Plateau has shown that the viscosity of the surface of a liquid is often different from that of its interior, and this fact is best illustrated by a solution of saponine in water. If a needle point be attached vertically to the bottom of a beaker, so that a small magnet, supported by it as a pivot, can turn freely on a horizontal plane, the magnet will readily follow the movements of the pole of a larger magnet held at some little distance from it. Let a solution of saponine be then poured in, until the small magnet just lies on the surface, and it will be found that the viscosity is so great that the small magnet scarcely stirs, even when the large one is brought quite close. If more solution be added, so that the magnet is immersed to a depth of a quarter of an inch, it moves again, almost as freely as when surrounded by air.

This experiment proves that the surface viscosity of saponine is much higher than that of its interior. A saponine bubble, owing to this high surface viscosity, thins very slowly, and never shows the colors which indicate great tenuity, and it might be thought that, in the case of soap solution, a similar limit is attained, but only when the film is much thinner. The uniform thickness of the black would then be attributed to the fact that when that thickness was reached, the viscosity prevented gravity from producing any further appreciable decrease in thickness. Such a view, however, fails to explain the definite boundary of the black, and must, therefore, be abandoned.

Turning next to the surface tension, we know that the surface of liquid is in a state somewhat analogous to that of a distended bladder. It tends to contract, and a liquid, if left to itself, always assumes that form which has the least possible surface for the given volume. It has generally been supposed that, when the film became so thin that the surface layers intermingled, the surface tension would diminish, and it remains to inquire whether the peculiarities of the black film are due to any such cause. Plateau and others have, experimentally, investigated the question as to whether the surface tension of a thin film was less than that of a thick one. On the other hand, it has been thought that the mere fact that a film can exist of which one part is very thin and another much thicker is a sufficient proof that there is no difference of tension between these two parts.

If a drop of alcohol or ether be allowed to fall on a thin layer of water spread on a sheet of glass, the higher surface tension of the water overcomes that of the alcohol, and tears the drop asunder. If two parts of a film were of different surface tensions, it must, it has been contended, break. It is, however, I think, possible that rupture might be delayed for a considerable time, if the surface viscosity were sufficiently high. Thus, if air be rapidly withdrawn from a thick bubble of soap solution, it maintains the spherical form. If the same experiment be tried with a solution of saponine, the surface viscosity is so great that the liquid is unable to follow the retreating air, and the film assumes the form of a wrinkled, purse-shaped bag (shown in Fig. 5), the surface of which is much larger than

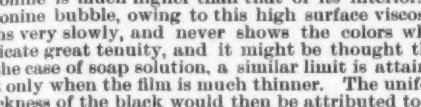


FIG. 5.

that of a sphere of the same volume. If it be then left to itself, the surface tension slowly overcomes the resistance opposed to it, the creases and wrinkles disappear, and the film gradually assumes the spherical form.

It does not, therefore, seem absurd to suppose that a small difference of surface tension might exist between two parts of a film, the viscosity of which prevented immediate rupture, just as in the case of the saponine solution it prevented the immediate assumption of the spherical form. Before our own observations were made, Ludtge had, indeed, announced that the surface tensions of thick and thin films were different. Van der Mensbrugghe had found an explanation in the cooling of the thicker film by the continual renewal of its surface as the liquid drained away. Maxwell, in his article on capillary action in the "Encyclopædia Britannica," had expressed a hope that observations on the surface tension of very thin films might lead to an increase in our knowledge of molecular forces. These considerations, combined with the facts that all previous observers had dealt with films at least ten times thicker than the black ones which we have been in the habit of observing, and that preliminary observations proved that Van der Mensbrugghe's explanation of the differences of tension he had observed was insufficient, have led Professor Reinold and myself to investigate the question afresh.

The method which we adopted is a modification of that employed by Ludtge, and is based upon the fact that a curved film exerts a pressure upon the air which it incloses. The pressure increases with the curvature of the film, and an apparatus by means of which this can readily be shown to a large audience is represented in Fig. 6. Glass tubes, furnished with stopcocks, are fused together, and bent into the shape drawn in the figure. The lower ends, E and F, are placed in front of the lantern, and images of them are formed upon a screen. To the upper end, A, a piece of India rubber tubing is attached. Stopcocks B and C being open, and D closed, a film is formed at E by moistening the end of the tube with soap solution, and blown out into a bubble. Then C is closed, D opened, and a similar operation is repeated at F, the two bubbles being of different diameters. Communication with the external air is then cut off by closing B. If, as represented in the figure, the bubble attached to E is the smaller, and therefore the more curved, the air within it is under a greater pressure than that inclosed by F. This is proved by opening C, when the smaller bubble contracts, and the larger expands, until practically the whole of the air previously contained by both bubbles is forced into the larger one. A cylindrical film exerts the same pressure on the inclosed air as a sphere of double its diameter.

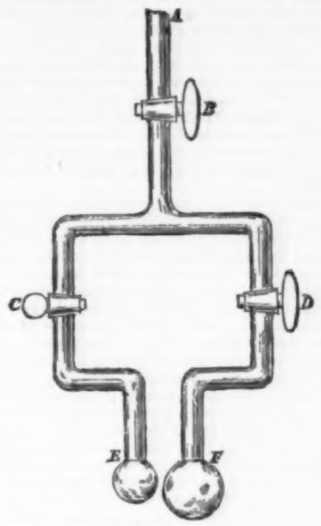


FIG. 6.

This may be illustrated by apparatus, a section of the essential parts of which is represented in Fig. 7. A small iron ring, A A, is placed in a shallow saucer, above the edge of which it slightly projects. The ring and saucer are nearly filled with liquid. A second ring, C, can be moved up and down by rack work. Air can be blown into it through the tube, D. Films are formed at the upper and under lips of C. It is brought near to A, air is forced in, two bubbles are formed, of which the lower adheres to A, and by withdrawing C, and regulating the total volume, a liquid cylinder and

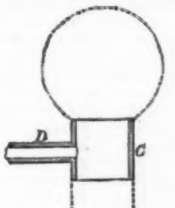


FIG. 7.

sphere can be obtained, in communication with each other, and in equilibrium. If more air than is necessary is supplied, the diameter of the sphere increases, and the pressure it exerts falls off. In order that the cylinder may also exert less pressure, it must become dice-box shaped.

It is thus easy to illustrate the paradoxical fact that, the larger the quantity of air supplied, the smaller does the volume of the lower film become. In this experiment, the sphere and the cylinder are formed of the same liquid, and possess the same surface tension, but if, after equilibrium had been established, the tension of one (say the cylinder), were to diminish, it would exert a less pressure on the air than before, and it would be compelled to bulge by the greater pressure still exerted by the other film (the sphere). If the changes in the dimensions of the sphere and cylinder were measured, we could calculate the change in the surface tension of the cylinder which had caused them. Though the arrangement of the apparatus was different, the principle of the method by which we compared the surface tensions of thick and thin films is the same as that of such an experiment. We balanced, as it were, the pressures exerted by two films against each other when both were thick, and they were again compared when one had become black, while the other had, by various means, been prevented from thinning. The measurements were beset by a good many difficulties, of which I may mention one.

The surface of the liquid, if newly formed, had a higher surface tension than if it had been exposed to the air for some time. This was probably due to the difficulty of keeping the surface free from impurity. When a new surface is formed, the surface tension does not assume its final value for a quarter of an hour. Any method of thickening the films should, therefore, be chosen so as to reduce the necessary disturbance of the surface to a minimum. We have found that, if an electric current be passed downward through a film, it accelerates its thinning, while if it be passed upward, it retards it, or even thickens the film. This can be shown as a lecture experiment, by means of the apparatus shown in Fig. 8. Two horizontal wires, A and B, are attached together by cocoon fibers. The upper one, A, can be raised and lowered by rack work, and a film is formed by immersing it in soap solution contained in a saucer.

On withdrawing it, a plane film forms between the fibers, the light reflected from which is, by means of a lens, used to form an image of the film upon the screen. Wires dipping into the liquid, and attached to the supports of A, convey, when the circuit is complete, a current from fifty Grove cells up the film. When the current passes, the colors, which have previously been traveling down the film, begin to rise. By using the electric current to keep one of the films thick, and by waiting, after any disturbance of the surface, for a time sufficient to allow the effects of that disturbance on the surface tension to die out, we were able to prove that no measurable difference of tension existed between a black film formed in the ordinary way and the thick films with which it was compared, some of which were more than one hundred times thicker than itself. The sensitiveness of the method was such that we could certainly have detected a difference of one-half per cent.

It is a significant fact that the black sometimes forms in an extraordinary way. Instead of spreading slowly over the film, a convulsion takes place, and it covers the whole, or the greater part, of the film in a few seconds. Such an event is generally followed by the immediate rupture of the film. In four cases, however, the film has lasted long enough to enable us to obtain a measure of its tension, and in all four cases it was unmistakably less than that of a thick film. These observations suggest a field for further, though very difficult, investigation; but at present it would be unwise to lay too much stress upon them, and we must confine our conclusions to the slow forming black, which we have studied fully.

One other experiment I must describe, which may serve to link the two cases together. If an electric current be passed up a film which is partly black and partly colored, it will, under favorable conditions,

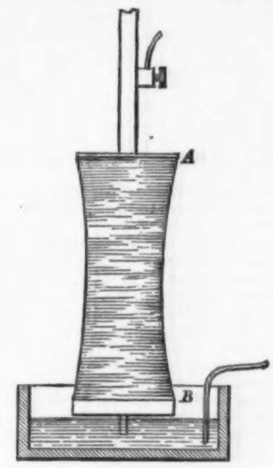


FIG. 8.

obliterate the sharp edge of the black. Matter is carried by the current from the thicker to the thinner parts of the film, the discontinuity is bridged over, and the thickness increases gradually from the black to the colored parts. As soon, however, as the circuit is broken, and the current ceases to act, the gray intermediate to the black, and the white of the first order, disappears, and in from ten to fifteen seconds the sharp edge of the black is restored as clearly as before. It is clear from this experiment that the gray is an unstable thickness, which cannot persist if the film be left to itself. A gray film tends to separate into two parts, one thicker, and one black and thinner than itself.

On considering all these facts, Professor Reinold and I, being of the same opinion as Professor Darwin, the president of section A, who lately reminded us that the mere observation of phenomena is of little use, unless we attempt to fit them together and to frame them in a theory, suggested in a paper, lately sent in to the Royal Society, that the best explanation would be found in assuming that, when the thickness of the film is a little greater than that proper to the black, the surface tension first diminishes and then increases again; in other words, that the apparent discontinuity is caused by a minimum of surface tension. It was not till some weeks afterward that we discovered that Sir William Thomson had, in the early part of the present year, made the same suggestion. His conclusion was based upon our earlier experiments, and he was the first to draw it, though we also arrived at it independently. To comprehend how a minimum of surface tension would produce the observed result, it is well to remember that the film is attached to its solid supports by a ring of thicker liquid. Let us suppose that, when the upper part of the film reaches a certain thickness, the tension falls off. This part of the film would then be extended, and its thickness further reduced, by the greater surface tension of the liquid ring and of the thicker parts of the film itself.

The rate at which this operation was conducted would, as we have seen, depend upon the relative magnitudes of the difference of surface tension and of the viscosity. If, as the upper part became thinner, its tension further diminished, the rate of thinning would increase; but if, after a certain thickness was reached, the tension increased, it would again diminish. Equilibrium would be restored when the thickness of the thinner part of the film was such that its surface tension was once more equal to that of the thick part. This hypothesis would explain all the known facts. The thickness of the black is uniform, because for that thickness only is the surface tension equal to that of a thick film. It may vary between narrow limits on different occasions, because the surface tensions of films formed of the same liquid are (probably from accidental causes) on different occasions different. The thickness of the thicker part of the film which is in contact with the black may, however, vary widely, as its tension is independent of its thickness. It remains to explain the explanation. Is there any rational method of accounting for the assumed minimum of surface tension? Here, I think, the clew to the problem has been given by Maxwell. He pointed out that, if the forces in play between the molecules of a liquid were at certain distances attractive, and at other distances repulsive, they would produce in a thinning film maxima and minima of surface tension, such as that which the hypothesis I have laid before you demands.

Our observations prove that the difference between the minimum and ordinary values of the tension must be very small, and that, since when the gray is artificially formed by the electric current the restoration of the definite boundary of the black takes place quickly when the circuit is broken, the viscosity of the thin film is not extraordinarily high. Whatever may be ultimately thought of these views, and however they

may be modified in the light of wider knowledge, I venture to think I have laid before you a number of facts which must be considered whenever a satisfactory dynamical theory of liquids is produced. It may be that thus the apparent discontinuity in the thickness of a film at the edge of the black will be found to be closely related to the far greater and more important apparent discontinuity which separates a liquid from its vapor.

THE MUIR GLACIER.

By G. FREDERICK WRIGHT.

1.—DESCRIPTION OF GLACIER BAY.

THE Muir glacier enters an inlet of the same name at the head of Glacier Bay, Alaska, in latitude 58° 50', longitude 136° 40' west of Greenwich.* (See Fig. 1.) Glacier Bay is a body of water about thirty miles long and from eight to twelve miles wide (but narrowing to about three miles at its upper end), projecting in a northwest direction from the eastern end of Cross Sound. The peninsula inclosed between Glacier Bay, Cross Sound, and the Pacific Ocean is from thirty to forty miles wide, and contains numerous lofty mountain peaks. Mount Crillon, opposite the head of the bay, is 15,900 feet high, and Mount Fairweather, a little farther north, is 15,500 feet. Mounts Lituya and La Perouse, lying on either side of Crillon, are not far from 10,000 feet above the sea. To the east, between Glacier Bay and Lynn Channel, is a peninsula extending considerably south of the mouth of the bay, and occupied by the White Mountains, whose height I am unable to ascertain, but probably having no peaks exceeding 10,000 feet.

Near the mouth of Glacier Bay is a cluster of low islands named after Commander Beardslee, of the U. S. Navy. There are twenty-five or thirty of these, and they are composed of loose material, evidently glacial debris, and are in striking contrast to most of the islands and shores in southeastern Alaska. These, also, like all the other land to the south, are covered with evergreen forests, though the trees are of moderate size. The islands and shores in the upper part of the bay are entirely devoid of forest. Willoughby Island, near the middle of the bay, is a bare rock, about two miles long and 1,500 feet high, showing glacial furrows and polishing, from the bottom to the top. Several other smaller islands of similar character in this part of the bay show like signs of having been recently covered with glacial ice.

1.

The upper end of the bay is divided into two inlets of unequal length, the western one being about four miles wide and extending seven or eight miles (estimated) in the direction of the main axis of the bay to the northwest. The eastern, or Muir, inlet is a little over three miles wide at its mouth, and extends to the north about the same distance, narrowing, at the upper end, to a little over one mile, where it is interrupted by the front of the Muir glacier. The real opening between the mountains, however, is here a little over two miles wide, the upper part on the eastern side being occupied with glacial debris covering a triangular space between the water and the mountain about one mile wide at the ice front and coming to a point three miles below, beyond which a perpendicular wall of rock 1,000 feet high rises directly from the water. The mountain on the west side of Muir inlet, between it and the other fork of the bay, is 2,900 feet high. That on the east is 3,150 feet high, rising to about 5,000 feet two or three miles back. The base of these mountains consists of metamorphic slate, whose strata are very much contorted—so much so, that I found it impossible, in the time at command, to ascertain their system of folds. Upon the summits of the mountains on both sides are remnants of blue crystalline limestone preserved in synclinal axes. In the terminal moraine deposited in front of the glacier on its eastern side are numerous bowlders of very pure white marble coming in medial moraines originating in mountain valleys several miles to the east. Granitic bowlders are also abundant.

2.—DIMENSIONS AND CHARACTERISTICS OF THE MUIR GLACIER.

The width of the ice where the glacier breaks through between the mountains is 10,664 feet—a little over two miles. But, as before remarked, the water front is only about one mile. This front does not form a straight line, but terminates in an angle projecting about a quarter of a mile below the northeast and northwest corners of the inlet. The depth of the water 300 yards south of the ice front is (according to the measurement of Captain Hunter of the steamer Idaho) 516 feet near the middle of the channel; but it shoals rapidly toward the eastern shore. According to my measurements, taken by leveling up on the shore, the height of the ice at the extremity of the projecting angle in the middle of the inlet was 250 feet; and the front was perpendicular. Back a few hundred feet from the projecting point, and along the front nearer the shores, the perpendicular face of the ice was a little over 300 feet. A little farther back, on a line even with the shoulders of the mountains between which the glacier emerges to meet the water, the general height is 408 feet. From here the surface of the glacier rises toward the east and northeast about 100 feet to the mile. On going out in that direction on the ice seven miles (as near as I could estimate), I found myself, by the barometer, 1050 feet above the bay.

The main body of the glacier occupies a vast amphitheater, with diameters ranging from thirty to forty miles. This estimate was made from various views obtained from the mountain summits near its mouth when points whose distances were known in other directions were in view. Nine main streams of ice unite to form the grand trunk of the glacier. These branches come from every direction north of the east and west line across the mouth of the glacier; and no less than seventeen sub-branches can be seen coming in to join the main streams from the mountains near the rim of the amphitheater, making twenty-six in all. Numerous rocky eminences also rise above the surface of the ice, like islands from the sea. The two of these visited, situated about four miles back from the front, showed that they had been recently covered with ice, their surfaces being smoothed and scored, and glacial debris being deposited everywhere upon them. Upon the side from which the ice approached these islands (the stoss side) it rose, like breakers on the seashore, several hundred feet higher than it was immediately on the lee side. A short distance farther down on the lee side, however, the ice closes up to its normal height at that point. In both instances, also, the lee side of these islands seemed to be the beginning of important subglacial streams of water; brooks running into them as into a funnel, and causing a backward movement of ice and moraine material, as where there is an eddy in the water. In both these cases the lee sides of these islands were those having greatest exposure to the sunshine. The surface of the ice on this side was depressed from one to two hundred feet below the general surface on the lee side.

The ice in the eastern half of the amphitheater is moving much more slowly than that in the western half. Of this there are several indirect indications. First, the eastern surface is much smoother than the western. There is no difficulty in traversing the glacier for many miles to the east and northeast. Here and there the surface is interrupted by superficial streams of water occupying narrow, shallow channels, running for a short distance and then plunging down into "*moulins*" to swell the larger current, which may be heard rushing along in its impetuous course far down beneath and out of sight. The ordinary light colored bands in the ice parallel with its line of motion are everywhere conspicuous, and can be followed on the surface for long distances. When interrupted by crevasses, they are seen to penetrate the ice for a depth of many feet, and sometimes to continue on the other side of a crevasse in a different line, as if having suffered a lateral fault. The color of the ice below the surface is an intense blue, and over the eastern portion this color characterizes the most of the surface. Numerous holes in the ice, penetrating downward from an inch or two to several feet, and filled with water, are encountered all over the eastern portion. Sometimes there is a stone or a little dirt in the bottom of these, but frequently there is nothing whatever in them but the purest of water. In the shallower inclosures on the surface, containing water and a little dirt, worms about as large around as a small knitting needle and an inch long are abundant.

3.—THE MORAINES.

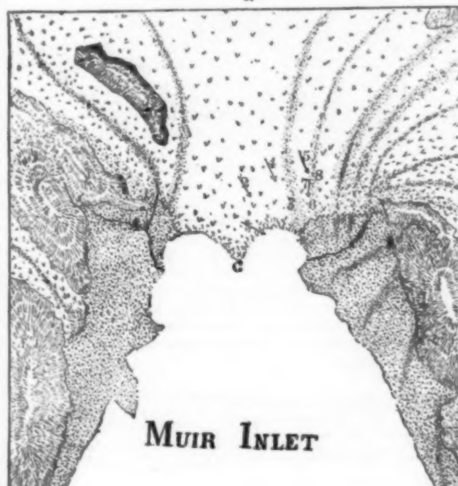
The character and course of the moraines on the eastern half of the glacier also attest its slower motion. There are seven medial moraines east of the north and south line, four of which come in to the main stream from the mountains to the southeast. (See Fig. 2.) Near the rim of the glacial amphitheater these are long distances, in some cases miles, apart; but, as they approach the mouth of the amphitheater, they are crowded closer and closer together near its eastern edge, until in the throat itself they are indistinguishably mingled. The three more southern moraines unite some distance above the mouth. One of these contains a large amount of pure marble. This moraine approaches the others on either side until the distance between them disappears, and its marble unites in one common medial moraine a mile or more above the mouth. The fifth moraine from the south is about 150 yards in width, five miles back from the mouth. It is then certainly as much as five, and probably eight, miles from the mountains from which the debris forming it was derived. All these moraines contain many large blocks of stone, some of which stand above the general mass on pedestals of ice, with a tendency always to fall over in the direction of the sun. One such block was twenty feet square and about the same height, standing on a pedestal of ice, three or four feet high. It is the combination of these moraines, after they have been crowded together near the mouth, which forms the deposit now going on at the northeast angle of the inlet just in front of the ice. Of this I will speak more fully in connection with the question of the recedence of the glacier. Similar phenomena, though on a smaller scale, appear near the southwest angle of the amphitheater.

4.—INDIRECT EVIDENCES OF MOTION.

The dominant streams of ice in the Muir glacier come from the north and the northwest. These unite in the lower portion to form a main current, about one mile in width, which is moving toward the head of the inlet with great relative rapidity. Were not the water in the inlet deep enough to float the surplus ice away, there is no knowing how much farther down the valley the glacier would extend. The streams of ice from the east and southwest have already spent the most of their force on reaching the head of the inlet; and, were it not for this central ice stream, a natural equilibrium of forces would be established here independent of the water, and no icebergs would be formed. The surface of this central current of motion is extremely rough, so that it is entirely out of the question to walk far out upon it. On approaching this portion of the glacier from the east, the transverse crevasses diagonal to the line of motion increase in number and size until the whole surface is broken up into vast parallelograms, prisms, and towers of ice, separated by yawning and impassable chasms scores and hundreds of feet in depth. Over this part of the ice the moraines are interrupted and drawn out into thinner lines, often appearing merely as patches of debris on separate masses of ice. This portion of the ice current presents a lighter colored appearance than other portions, and the roughened lines of motion can be followed, as far as the eye can reach, through distant openings in the mountains to the north and the northwest.

The comparative rapidity of the motion in this part of the ice is also manifest where it breaks off into the water at the head of the inlet. As already said, the perpendicular front of ice at the water's edge is from 250 ft. to 300 ft. in height. From this front there is a constant succession of falls of ice into the water, accompanied by loud reports. Scarcely ten minutes either day or night passed during the whole month without our being startled by such reports, and frequently they were like thunder claps or the booming of cannon at the bombardment of a besieged city, and this though our camp was two and a half miles below the ice front. Sometimes this sound accompanied the actual fall of masses of ice from the front, while at other times it was merely from the formation of new crevasses or the enlargement of old ones. Repeatedly I have seen vast columns of ice, extending up to the full height of the front, topple over and fall into the water. How far these columns extended below the water could not be told accurately, but I have seen bergs floating away which were certainly 500 ft. in length. At other times masses would fall from near the summit, breaking off part way down, and splashing the spray up to the very top of the ice, at least 250 ft. The total amount of ice thus falling off could not be directly estimated, but it is enormous. Bergs several hundred feet long and nearly as broad, with a height of from 20 ft. to 60 ft., were numerous, and constantly floating out from the inlet. The steamer met such one hundred miles away from the glacier. The smaller pieces of ice often so covered the water of the inlet miles below the glacier that it was with great difficulty that a canoe could be pushed through. One of the bergs measured was 60 ft. above the water and about 400 ft. square. The portion above water was somewhat irregular, so that probably a symmetrical form 30 ft. in height would have contained it. But, even at this rate of calculation, the total depth would be 240 ft. The cubical contents of the berg would then be almost 40,000,000 ft. Occasionally, when the tide and wind were favorable, the inlet would for a few hours be comparatively free from floating ice; at other times it would seem to be full.

2.



5.—SUBGLACIAL STREAMS.

The movements of the glacier in its lower portions are probably facilitated by the subglacial streams issuing from the front. There are four of these of considerable size. Two emerge in the inlet itself, and come boiling up, one at each corner of the ice front, making a perceptible current in the bay. There are also two emerging from under the ice where it passes the shoulders of the mountains forming the throat of the glacier. These boil up, like fountains, two or three feet, and make their way through the sand and gravel of the terminal moraine for about a mile, and enter the inlet 250 or 300 yards south of the ice front. These streams are, perhaps, 3 ft. deep and from 20 ft. to 40 ft. wide, and the current is very strong, since they fall from 150 ft. to 250 ft. in their course of a mile. It is the action of the subglacial streams near the corners of the inlet which accounts for the more rapid recession of the glacier front there than at the middle point projecting into the water south of the line joining the east and west corners. It was also noticeable that the falls of ice were much more frequent near these corners, and the main motion of the ice, as afterward measured, was not toward the middle point projecting into the inlet, but toward these corners where the subglacial streams emerged below the water.

6.—DIRECT MEASUREMENT OF THE VELOCITY.

No small difficulty was encountered in securing direct measurements of the motion; and, as the results may be questioned, I will give the data somewhat fully. As it was impossible to cross the main current of the glacier, we were compelled to take our measurement

* The maps have been largely made from original data. They are square with the compass, which bears here, however, 29° east of north.

by triangulation. But, even then, it seemed at first necessary to plant flags as far out on the ice as it was safe to venture. This was done on the second day of our stay, and a base-line was established on the eastern shore, about a mile above the mouth, and the necessary angles were taken. But, on returning to repeat the observations three or four days afterward, it was found that the ice was melting from the surface so fast that the stakes had fallen, and there were no means at command to make them secure. Besides, they were not far enough out to be of much service. It appeared, also, that the base-line was on a lateral moraine, which was, very likely, itself in motion. But by this time it had become evident that the masses of ice uniting to compose the main stream of motion retained their features so perfectly from day to day that there was no difficulty in recognizing many of them much farther out than it was possible to venture to plant stakes. Accordingly, another base-line was established on the east side, opposite the projecting angle of ice, in the inlet. From this position, eight recognizable points in different portions of the ice field were triangulated—the angles being taken with a sextant. Some of the points were triangulated on five different times, at intervals from the 11th of August to the 2d of September. Others were chosen later, and triangulated a fewer number of times. In all cases given the angles were taken independently by Mr. Prentiss Baldwin, of Cleveland, and myself, and found to agree.

The base-line finally chosen (marked B on Fig. 2) was at the foot of the mountain, exactly east, by the compass, from the projecting angle of ice in the inlet. The elevation of the base-line was 408 ft. above tide—corresponding to that of the ice front. The distance of this projecting point of ice (marked C on Fig. 2) from the base line was 8,534 ft., and it remained very nearly stationary during the whole time—showing that the material breaking off from the ice front was equal to that pushed along by the forward movement. Satisfactory observations were made upon eight other points, numbered and located on Fig. 2.

No. 1 was a pinnacle of ice 1,476 ft. N. by 30° E. from C. The movement from August 14 to August 24 was 1,653 ft. E. by 15° S. After this date the pinnacle was no longer visible, having disappeared along the wasting line of front between C and the subglacial stream at the northeast corner of the inlet.

No. 2 was a conspicuous pinnacle of ice 2,416 ft. N. by 16° E. of C. Observations were continued upon this from August 11 to September 2. The total distance moved during that time was 1,417 ft., or about 65 ft. per day. From August 14 to August 24 the movement was 715 ft., or about 71 ft. per day. The difference is, however, perhaps due to the neglect to record the hours of the day when the observations were taken. As these observations were wholly independent of each other, their substantial concordance demonstrates that there was no serious error in the observations themselves. The direction of movement of this point of ice was very nearly the same as that of the preceding, namely, E. 16° S. This, also, is toward the subglacial stream emerging from the northeast corner of the inlet.

No. 3 was observed only from August 20 to August 24. It was situated 3,893 ft. N. by 62° E. of C, and moved 105 ft. in a westerly direction. The westerly course of this movement probably arose from its being near where the easterly and northeasterly currents joined the main movement.

No. 4 was 5,115 ft. N. 42° E. of C, and moved from August 20 to August 24, 148 ft. in a southeasterly direction.

No. 5 was 5,580 ft. N. 48° E. of C, and moved 289 ft. from August 20 to August 24, in a direction E. by 39° S.

No. 6 was 5,473 ft. N. 70° E of C, and moved 232 ft. from August 11 to September 2 in a direction S. 66° E.

No. 7 was 6,903 ft. N. 59° E. of C. and moved 89 ft. between August 14 and August 24 in a direction S. 3° E., about 9 ft. per day.

No. 8 was 7,507 ft. N. 62° E. of C, and moved 265 ft. from August 14 to August 24 in direction S. 56° E. These last three points lay in one of the moraines on the east side of the line of greatest motion and parallel with it. These moraines are much interrupted in their course by gaps.

Not having a logarithmic table with me in camp, these points brought under observation proved much nearer the eastern side than I supposed at the time. But the distances are so great that nothing better could be done from the base line chosen. I should also have established another base-line on the western side, but stormy weather, and the difficulty of crossing at the times set for doing so, interfered. As the problems are worked out it is observable that the points chosen were all east of the center of the main line of most rapid motion, and are tending with varying velocity toward the northeast corner of the inlet, where the powerful subglacial stream emerges from below the water level. Doubtless, on the other side of the center of motion, and at the same relative distance from the front, the ice would be found tending toward the southwest corner, where a similar subglacial stream emerges. I could but wish that some of the points observed had been farther back from the front, but must take the facts as they are. I supposed some of them were farther away, but, as they were projected on the distant background, the true position could not be told until the actual working out of the problems.

From these observations, it would seem to follow that a stream of ice presenting a cross section of about 3,500,000 sq. ft. (5,000 ft. wide by about 700 ft. deep) is entering the inlet at an average rate of 40 ft. per day (70 ft. in the center and 10 ft. near the margin of movement), making about 140,000,000 of cu. ft. per day during the month of August. The preceding remarks upon the many indirect evidences of rapid motion render the calculation perfectly credible. What the rate may be at other times of the year there are at present no means of knowing.

7.—THE RETREAT OF THE GLACIER.

The indications that the Muir glacier is receding, and that its volume is diminishing, are indubitable and numerous. Little regard need to be paid to the record of Vancouver a hundred years ago, for he did not attempt to enter the bay at all, finding it so full of ice near its mouth as to deter him from it, hence his testimony that the opening was full of ice is so indefinite that it has little bearing upon the condition of the upper portions of the bay at that period of time. Nor need any reliance be placed on the traditions of the Indians to the effect that within the memory of their grandfathers the ice extended several miles farther down than at the present time.

The Indians now rarely visit the head of the inlet, and the quantity of ice floating on the surface varies so much from day to day, and presumably from month to month, that great diversity of impressions might be received at times separated by even short intervals. The convincing evidence of the recent retreat of the glaciers of this bay from ground formerly occupied by them is of a physical character.

The islands of Southern Alaska are ordinarily covered with forests of cedar, hemlock and fir up to the level of perpetual snow. To this rule the shores and islands of the upper part of Glacier Bay are a striking exception. Near the mouth of the bay forests continue to occur as in other parts, only on a diminished scale, but in the upper half of the bay all shores and islands are perfectly bare of forests, and the rocks retain in the most exposed situations fresh grooves and striæ of glacial origin.

It would be impossible for rocks so exposed in such a climate to retain these for an indefinite length of time. Far up on the mountains, also, there are remnants of glacial debris in situations such that the material could not have resisted erosive agencies for any great length of time. The triangular shaped terminal moraine on the eastern side, just below the ice front, presents some interesting features bearing on the same point. This extends three miles below the glacier, and in its lower portions is thinly covered with vegetation. This covering becomes less and less abundant as the glacier is approached, until, over the last mile, scarcely any plants at all can be found. Apparently this is because there has not been time for vegetation to spread over the upper portion of the moraine since the ice withdrew, for on the mountains close by, where the exposure has been longer, there is a complete matting of grass, flowering plants, and shrubs.

Again, in this triangular moraine covered space, there are five distinct transverse ridges, marking as many stages in the recession of the ice front. (See Fig. 2.) These moraines of retrocession run parallel with the ice front on that side, and at about equal distances from each other, each one rising from the water's edge to the foot of the mountain, where they are 408 feet above tide. An inspection of the upper moraine ridge shows the manner of its formation. This transverse ridge is one-half mile below the ice front, and is still underlaid in some portions with masses of ice thirty feet or more in thickness, which are melting away on their sides and allowing the debris covering them to slide down about their bases. Kettle holes are in all stages of formation along this ridge. The subglacial stream emerging from the southeast corner of the glacier next the mountain rushes along just in the rear of this moraine ridge and in front of a similar deposit in process of formation on the very edge of the ice where the medial moraines spoken of terminate. Eventually this stream will break out in the rear of that deposit, also, and leave another ridge similar to the one now slowly settling down into position south of it. This first ridge south of the subglacial stream, with its ice still melting in exposed positions under its covering of gravel, cannot be many years old.

Still another sign of the recent date of this whole moraine appears at various places where water courses coming down from the mountain are depositing superficial deltas of debris upon the edge of the older glacial deposit. These deltas are very limited in extent, though the annual deposition is by no means insignificant.

At the southern apex of the moraine, three miles below the ice front, and but one or two hundred yards from our camp, great quantities of debris came tearing down in repeated avalanches during a prolonged season of rain. Twenty-five years would be ample time for the formation of the cone of debris at the foot of this line of avalanches. Thus there can be no reasonable doubt that during the earlier part of this century the ice filled the inlet several miles farther down than now. And there can be scarcely less doubt that the glacier filled the inlet, as recently as that, 1,000 or 1,500 feet above its present level near the front. For the glacial debris and striæ are very marked and fresh on both mountains flanking the upper part of the inlet up to 2,500 feet, and the evidences of an ice movement in the direction of the axis of the bay are not wanting as high as 3,700 feet on the eastern mountain, upon which I found fresh striæ running north by south and directly past the summit, which rises 1,000 or 1,500 feet still higher just to the east.

8.—A BURIED FOREST.

All this is necessary to a comprehension of one of the most interesting of problems, presented by the buried forests near the southwest corner of the glacier. (See A, Fig. 2.)

Below this corner, and extending for about a mile and a half, there is a gravel deposit, similar to that on the eastern side, except that it is not marked by transverse ridges, but is level-topped, rising gradually from about 100 ft. at its southern termination to a little over 300 ft. where it extends north and west of the ice front. (See Fig. 2.) The subglacial stream entering the inlet just below the southwest corner of the ice emerges from the ice about a mile farther up, on the north side of the projecting shoulder of the western mountain, which forms that side of the gateway through which the ice enters the inlet. This stream comes principally from the decaying western branch of the glacier before alluded to, and, after winding around the projecting shoulder of the mountain (this shoulder is 315 ft. A. T.), has worn a channel through the gravel deposit lying between the lower mile of the glacier and the mountain a short distance to the southwest. About half way down, a small brook, coming from between this latter mountain and that whose shoulder forms the western part of the gateway just north of it, joins the main stream issuing from the glacier on this side. Where these streams unite at A they are now uncovering a forest of cedar trees in perfect preservation, standing upright in the soil in which they grew, with the humus still about their roots. An abundance of their cones, still preserving their shape, lies about their roots, and the texture of the wood is still unimpaired. One of these upright trunks measured 10 ft. in circumference about 15 ft. above the roots. Some of the smaller upright trees have their branches and twigs still intact, preserving the normal conical appearance of a recently dead cedar tree. These trees are in various stages of exposure. Some of them are uncovered to the roots, some are washed wholly out of the soil, while others are still buried and standing upright in horizontal layers of fine sand and gravel, some with tops projecting from a depth of 20 ft. or 30 ft., others being doubtless entirely covered. The roots of these trees are in a compact, stiff clay stratum, blue in color, without grit, intersected by numerous rootlets as long as a knitting needle, which is, in places, 20 ft. thick. There is, also, occasionally in this substratum of clay a small fragment of wood, as well as some smooth pebbles from an inch to two feet in diameter. The surface of this substratum is at this point 85 ft. above the inlet. The deposit of sand and gravel covering the forest rises 115 ft. higher, and is level-topped at that height, but rising toward the north till it reaches the shoulder of the mountain at an elevation of 300 ft. The trees are essentially like those now growing on the Alaskan mountains. Many of them have been violently broken off from 5 ft. to 20 ft. above their roots. This has been done by some force that has battered them from the upper side at the point of fracture. Evidently, cakes of ice brought down by the streams indicated in the map, when flowing at various higher levels than now, have accomplished this result; for the trunks in the main stream were battered on the north side, while those in the gully, worn by the lateral stream, were battered from the west side.

From this description, the explanation of this buried forest would seem to be evident enough. At some period, when the ice occupied only the upper part of the valley to the north of this point, forests grew over all the space lying southwest of the present ice front. As the ice advanced to near its present position, the streams carrying off the surplus water from the western half of the advancing glacier were suddenly turned into the protected space occupied by this forest, where they deposited their loads of sand and gravel. A cause very likely combining to facilitate deposition in this spot has not yet been spoken of, but is evident when on the ground, and from a glance at the map. A transverse valley passes just below this point from Muir inlet to the western inlet into which Glacier Bay divides. This transverse valley is at present occupied by a decaying glacier opening into both inlets, and sending a subglacial stream, through a long, narrow series of moraines, into Muir inlet about two miles to the south. Now, when a general advance of the ice was in progress, this transverse stream probably pushed itself down into the inlet across the path of the ice moving from the north, and so formed an obstruction to the water running from the southwest corner of the main glacier, thus favoring the rapid deposition which so evidently took place. When this inclosed place was filled up, and the advancing ice had risen above and surmounted the projecting shoulder of the mountain just to the north, that rocky barrier protected a portion of the forest from the force of the ice movement, causing the ice to move some distance over the top of the superincumbent gravel before exerting its full downward force. Thus sealed up on the lee side of this protecting ridge of rock, there would seem to be no limit to the length of time the forest might be preserved. I see no reason why this forest may not have antedated the glacial period itself.

The existence of other forests similarly preserved in that vicinity is amply witnessed to by many facts. One upon the island near the west shore, four miles south, is now exposed in a similarly protected position. Furthermore, the moraine, already described on the east side of the inlet, contains much wood ground up into slivers and fragments. Indeed, our whole dependence during the month for fuel was upon such fragments lying exposed in the moraine. Occasional chunks of peat or compact masses of sphagnum formed a part of the debris of this moraine. These also occurred on some of the medial moraines on the eastern side. I did not go up them far enough to learn directly their origin. But, as no forests were visible anywhere in that direction, it is presumable that they had been recently excavated from preglacial forests similar in situation to that now exposed on the west below the ice front.

The capacity of the ice to move, without disturbing them, over such gravel deposits as covered the forests, is seen in the present condition of the southwestern corner of the glacier itself. As the ice front has retreated along that shore, large masses of ice are still to be seen lapping over upon the gravel. These are portions of the glacier still sustained in place by the underlying gravel, while the water of the inlet has carried the ice from the perpendicular bank clear away. This phenomenon, and that of the general perpendicular front presented by the ice at the water's edge, accords with the well-known fact that the surface of the ice moves faster than the lower portions. Otherwise, the ice columns at the front would not fall over into the water as they do.

9.—KAMES AND KETTLE HOLES.

The formation of kames and of the knobs and kettle holes characteristic both of kames, and terminal moraines, is illustrated in various places about the mouth of Muir glacier, but especially near the southwest corner just above the shoulder of the mountain where the last lateral branch comes in from the west. This branch is retreating, and has already begun to separate from the main glacier at its lower side, where the subglacial stream passing the buried forest emerges. Here a vast amount of water-worn debris covers the ice, extending up the glacier in the line of motion for a long distance.

It is evident from the situation that, when the ice stream was a little fuller than now, and the subglacial stream emerged considerably farther down, a great mass of debris was spread out on the ice at an elevation considerably above the bottom. Now that the front is retreating, this subglacial stream occupies a long tunnel, twenty-five or thirty feet high, in a stratum of ice that is overlaid to a depth in some places of fifteen or twenty feet with water-worn glacial debris.

In numerous places the roof of this tunnel has broken in, and the tunnel itself is deserted for some distance by the stream, so that the debris is caving down into the bed of the tunnel as the edges of ice melt away, thus forming a tortuous ridge, with projecting knolls where the funnels into the tunnel are oldest and largest.

At the same time, the ice on the sides at some distance from the tunnel, where the superficial debris was

thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the debris is sliding down the sides as well as into the tunnel through the center. Thus three ridges approximately parallel are simultaneously forming. When the ice has fully melted away, this debris will present all the complications of interlacing ridges, with numerous kettle holes and knobs characterizing the kames; and these will be approximately parallel with the line of glacial motion. The same condition of things exists about the head of the subglacial stream on the east side, also near the junction of the first branch glacier on the east with the main stream, as also about the mouth of the independent glacier shown on the map lower down on the west side of the inlet. (See Fig. 2.) The formation of kettle holes in the terminal ridges has already been referred to.

10.—TRANSPORTATION AND WASTE BY WATER.

Considerable earthy material is carried out from the front by the bergs. Pebbles and dirt were frequently seen frozen into them as they were floating long distances away. Just how many of the bergs were formed from ice that originally rested on the bottom of the inlet, I have no means of telling. That some were so formed seems exceedingly probable, if for no other reasons because of the great amount of debris that was sometimes seen frozen into them. It is by no means certain that the subglacial streams boiling up near the upper corners of the inlet were beneath the lowest stratum of ice. Some small streams were seen pouring out from the face of the ice half way up from the water. It seems likely that a great amount of sediment becomes incorporated in cavities in the center of the glacier through the action of these subglacial streams, and so is ready for transportation when the masses break loose.

There were two pretty distinct lines of motion in the currents of the inlet, corresponding to those originating in the subglacial streams, so that ordinarily the ice floes arranged themselves in the inlet along definite lines. But the tides were so high as sometimes to cause much irregularity. Frequently, large icebergs would be seen moving up the lines of current or diagonal to them. The upper part of the inlet was filled with the muddy water coming from the subglacial streams. The line separating this muddy water from the clear water of the bay was driven, now one way and now another, according to the influence of the tide. The steamer's screw brought up much muddy water from below the surface some distance down the bay, and where the surface was clear. The sediment forming over the bottom of the bay must resemble the loess of the Missouri and Mississippi valleys.

11.—OTHER GLACIERS REACHING THE BAY.

Besides the Muir glacier, there are four others of large size entering the longer inlet to the west. (See Fig. 1.) These have their origin on the flanks of Mounts Crillon and Fairweather. They have never been studied, but are apparently as accessible as the Muir. Professor Muir and Rev. Mr. Young are the only well-informed persons who have visited them, and their stay was brief. I went about half way up the inlet, on its east side, and took some photographs from points where the whole outlines could be seen. I also saw them from the mountains on the east side. The general appearance does not differ materially from that of the Muir glacier. To complete the study one needs a small steam launch and more ample time and preparation than we could command.

The moisture of the climate is a serious drawback to investigations in all that region, though this is very favorable to the growth of glaciers. The annual precipitation over southeastern Alaska averages from eighty to one hundred inches. The average number of days per annum on which rain or snow has fallen at Sitka during the last fifty years is 198, while some years it has been as high as 264. Fifteen of the twenty-nine days we were in Glacier Bay (from August 4 to September 2) were so rainy as to render observation impossible. The other days were, however, clear and beautiful beyond description. The absence of forests also renders it easy to climb the mountains and observe from them. It is to be hoped that other expeditions better fitted than ours, and prepared to spend a longer time, will soon make a more complete study of this now easily accessible and most fruitful field for glacial investigation.

12.—TEMPERATURE.

I append the record of the thermometer from August 20 to August 31, giving the mean of three readings each day taken at 8 A. M., 2 P. M., and 8 P. M. The temperature of the water in the upper part of the inlet was uniformly 40° F.

August 20	49·4° F.	August 26	51·9° F.
August 21	48·9° F.	August 27	46·1° F.
August 22	46·1° F.	August 28	50·5° F.
August 23	44·6° F.	August 29	45° F.
August 24	49·8° F.	August 30	54·8° F.
August 25	52·7° F.	August 31	50·5° F.

13.—FLORA.

The following is the list of plants, as identified by Professor Asa Gray, found in bloom about Muir inlet during the month of August. Where the altitude is not given, they were found near the tide.

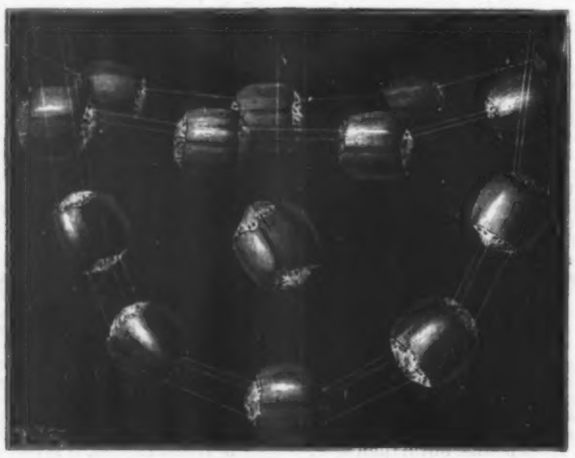
Arabis ambigua, Brong	Aug. 26	1600 A. T.
Arenaria peploides, L.	28	
Astragalus alpinus, L.	7	
Hedysarum boreale, Nutt	28	
Sanguisorba canadensis	6	
Lutkea sibbaldioides, Brong.	27	
Saxifraga lyalli, Engl.	26	1600 A. T.
" stellaris, L.	27	3000 A. T.
Parnassia fimbriata, Small	27	3000 A. T.
" palustris, L.	6	
Epilobium latifolium, L.	6	1600 A. T.
" origanifolium, Lam. (?)	28	
Solidago multiradiata, Ait	27	
Erigeron salsuginosus, Gray, arctic form	27	3000 A. T.
Antennaria margaritacea, arctic form	27	
Achillea millefolium, L., arctic var.	27	
Arnica obtusifolia, Les.	27	1200 A. T.
Campanula rotundifolia, L., var. Alaskana	28	
Gentiana platypetala (?)	27	
" menziesii (?)	27	
Mertensia maritima	7	
Castilleja parviflora, Brong.	28	
Salix vestita, Pursh	6	
Habenaria hyperborea, R. Br.	27	2650 A. T.
Luzula parviflora, Meyer		
Poa alpina, var. vivipara	26	1500 A. T.
Poa alpina, L.	26	1600 A. T.
Poa laxa, Haenke	26	1500 A. T.
Phleum alpinum, L.	26	1600 A. T.
Elymus mollis	6	
Hordeum, sp. (?)	6	

—*Amer. Jour. of Science.*

NECKLACES OF HAZELNUTS.

JUST beneath the external surface of the shell of the hazelnut there is a parallel series of ducts that extend from the bottom to the apex of the nut. At the base of the nut the mouths of these ducts may be discovered by cutting away a portion of the shell at the point where the brown portion of the latter meets the *hilum* or scar. The upper extremities of the ducts may be exposed to view by cutting away a portion of the nut at its apex. It is pointed out in *La Nature* (from which the engraving is taken), that a human hair can be passed through these ducts, from one end to the other, and that the nuts can thus be strung so as to form a sort of necklace.

The best hair to use for the purpose is woman's, as being longer and, as a general thing, finer than that of man. Care should be taken to introduce the root end of the hair into the aperture, inasmuch as human hair is serrated on the surface, and the sharp points are directed upward. The operation will perhaps require considerable manual dexterity for its performance.



NECKLACE OF HAZELNUTS.

METHOD OF BREAKING GLASS TUBE.

By ERNST BECKMANN.

THE author calls attention to the following simple method of breaking glass, which, though old, is not very generally known. In breaking a glass tube, *e. g.*, a combustion tube, a small scratch is made with a file at the required place. At each side of this scratch, and about one-half mm. away from it, a small roll of wet blotting paper is laid round the tube. The free space between is then heated all round over a Bunsen burner, or, better still, over a small blowpipe flame. A clean and even fracture is thus obtained, exactly between the two rolls, without dropping water on the hot glass. The rolls are made by cutting two strips of filter paper, sufficiently large to form rolls one to two mm. high, and two to four cm. wide. The strips are folded once, lengthways, laid on the table, moistened, flattened out, and then wrapped on to the tube, so that the fold lies nearest the file scratch, and fold lies accurately upon fold in the successive layers. The thickness of the rolls, and their distance apart, has, of course, to be varied, according to the diameters of the tubes. Equally good results are obtained with the thinnest test tubes, the thickest combustion tubes, beakers, flasks, and glass bell jars. In those cases where the sides are slanting, as, for instance, with funnels, an obvious alteration in the construction of the paper rolls need only be carried out.—*Zeitsch. f. Anal. Chem., vol. 25, part 4, p. 590; Analyst.*

GLAZE FOR ALBUMEN PRINTS.

PROF. DR. J. M. EDER recommends the following cerate for obtaining a high polish upon albumen prints: 100 grammes white wax is melted, and 100 grammes rectified oil of turpentine, together with 40 grammes dammar varnish, added. This mixture is poured into a dry glass. If it should appear too thick, add more turpentine. The mixture is rubbed well into the surface of the print with a rag, and gives an extraordinarily high glaze.

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